The Psammon of Bars and Beaches in Two Small Northwestern Minnesota Streams

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THE PSAMMON OF BARS AND BEACHES IN TWO SMALL NORTHWESTERN MINNESOTA STREAMS

by
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This Dissertation submitted by Richard D. Urban in partial fulfillment of the requirements for the Degree of Doctor of Philosophy from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

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Title THE PSAMMON OF BARS AND BEACHES IN TWO SMALL NORTHWESTERN MINNESOTA STREAMS

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ABSTRACT

Sand bars and beaches of the Mississippi (MR) and Wild Rice (WRR) Rivers, Minnesota, were sampled to allow determination of sand texture, capillarity, pore space, organic content, temperature, chemistry (pH, O_2, CO_3 and HCO_3 alkalinity, total hardness, Ca, Mg, PO_4, NH_3-N, and NO_2-N) of interstitial water, and composition and concentration of psammo-organisms, all in relation to current influences, distance above and below waterline, and depth into the sand.

Minimum and maximum values for capillary rise were 36-80 mm in the MR and 118-191 mm in the WRR; organic content was 217.4 mg/10cc sand for the MR and 377.1 mg/10cc sand for the WRR; and pore space comprised 22-25%, and 35-37% of the total sand volume for the MR and WRR, respectively. Submerged sand was frequently moved by stream currents.

Oxygen was absent from water 6-9 cm deep in exposed sand of both streams and in submerged sand of the WRR, but occasionally occurred in submerged sand in the MR (maximum 4.4mgl); pH decreased progressively from stream to submerged to exposed sand (exemplified as follows for the MR, 8.25, 7.15, and 6.95, respectively; and for the WRR by 7.6, 6.7, and 6.4, respectively) as decomposition became more localized. Carbonate alkalinity was not observed in interstitial water of either river. Bicarbonate alkalinity (range 114-252 mgl for the MR and 158-552 mgl for the WRR), total hardness (142-274 mgl MR and 189-693 mgl WRR), calcium (54-199 mgl MR and 99-395 mgl WRR), and magnesium (46-132 mgl MR and 24-287 mgl WRR) increased in the same order as pH, seemingly

because of ground water seepage, decomposition, and evaporation. Ammonia-nitrogen (0.0-5.0 mgl) and ortho-phosphate (0.0-5.84 mgl) were contributed to the psammon of the WRR by local surface drainage. Lower levels (0.0-2.0 mgl and 0.0-2.6 mgl, respectively) occurred in MR sand.

Composition and concentration of psammo-organisms were related to distance above and below waterline and to depth in the sand. Three hundred twenty-six (326) kinds of organisms were found in 700 samples. Potamopsammon organisms in descending numerical order were: diatoms (maximum number 2,181,824/cc sand MR and 441,470/cc sand WRR), blue-green algae (62,038 MR, 210,624 WRR), green algae (19,757 MR, 4,186 WRR), testaceous rhizopods (4,408 MR, 1,152 WRR), euglenophytes (2,480 MR, 2,160 WRR), rotifers (452 MR, 32 WRR), nematodes (216 MR, 184 WRR), tardigrades (188 MR, 8 WRR), dinoflagellates (112 MR, 0 WRR), oligochaetes (76 MR, 12 WRR), gastrotrichs (72 MR, 0 WRR), ciliates (56 MR, 4 WRR), dipteran larvae (56 MR, 30 WRR), ostracods (40 MR, 16 WRR), and hydrachnid larvae (40 MR, 0 WRR).

Potamopsammon organisms were most numerous in stable submerged sand. They were next most abundant in exposed sand within 70 cm of the waterline, newly formed sand bars under water, eroded portions of submerged sand, exposed sand 70+ cm above the waterline, and at the waterline, in that order.

The major portion of the population was usually located in the upper two centimeters of stable sand, but organisms penetrated to a depth of six centimeters. Concentration at any point or depth in submerged sand was subject to depletion or augmentation by current action. Organisms were most numerous at a depth of three or more centimeters in newly-formed submerged bars, partly from burial of established surface sand populations, and partly from loss of organisms from newly deposited sand.

Potamopsammon as exemplified by these study areas differs from lake psammon in the following respects: oxygen was absent in the interstitial water of exposed sand, a black layer was absent from the sand, fewer species of rotifers were present, harpactacoid copepods were absent, a more diverse blue-green algal flora was noted, algae were found in greater abundance, and organisms were found to exist at greater depths in potamopsammon than in lake psammon.

INTRODUCTION

Studies in the 1920's and 1930's demonstrated that sand beaches and shoals of lakes and streams possessed a wealth of microscopic life in water between sand grains. Sassuchin noted this interstitial population in moist beaches of the Oka River in 1926, and in 1927 Sassuchin, Kabanov, and Neiswestnova described this environment in some detail, suggesting that this living realm be designated "psammon". Sassuchin studied subsurface populations in air-borne steppe sands of Kirghiz in 1930, and in 1931 described conditions of life in water-accumulated sands of rivers and shifting sands of deserts. Microfauna differences in Oka River sand from midstream to banks were detailed by Neiwestnova-Shadina (1935).

Wiszniewski (1932, 1934 a, b, 1935, 1936, 1937, as cited in Neel, 1948) dealt primarily with rotifers inhabiting the sand of several Polish lakes and Varga (1938 as cited in Neel, 1948) reported on a preliminary study of psammon rotifers in Lake Balaton, Hungary. Some chemical and physical parameters and quantitative features of psammon organisms in an Austrian lake were described by Ruttner-Kolisko (1956). Availability of oxygen and its importance to animal distribution in some Swedish lake beaches was reported by Enckell (1968).

In the United States, two New Jersey lake beaches were the source of psammon rotifers described by Myers (1936). Pennak (1939a, b, 1940) reported on physical and chemical features of the psammon of several Wisconsin lakes, and described distribution of rotifers, copepods, and tardigrades. Physical, chemical, and biological features, and their relationships to shoal and shoreline dynamics, were studied by Neel (1948) in Douglas Lake, Michigan.

Works closely related to lake psammon were those of Moore (1939), dealing with the microscopic benthic fauna of Douglas Lake, Michigan; Cole (1955), who studied the microscopic benthic fauna of Lake Itasca and Crystal Lake, Minnesota; Round (1957 a, b, c, 1960, 1961, 1965), Round and Eaton (1966), Round and Happey (1965); and Harper (1969), who were concerned with freshwater epipelic microflora associations.

Aside from the Oka River studies of Sassuchin (1926, 1931), Sassuchin et al. (1927), and Neiwestnova-Shadina (1935), only Ruttner-Kolisko's 1961 study of the microfauna of the exposed banks of the Ybbs and Donau Rivers in Austria is concerned with stream psammon. Works closely related to potamopsammon have been those of Butcher (1932) and Douglas (1958) who studied the benthic algae of some English streams.

This study was undertaken to learn more detailed responses of the psammon to the stream environment than has previously been attempted, to compare stream dynamics to those operative in lakes as described primarily by Neel, and to determine any unique features of the potamopsammon environment and population.

STUDY AREAS

Study sites were established on the Mississippi River one-half mile below its "headwaters" in Lake Itasca, and on the Wild Rice River one mile east of Mahnomen, Minnesota (Figure 1). Headwaters of the two rivers lie only fourteen miles apart; both begin in a bog-forest successional community, but the Wild Rice River enters the prairie croplands of the glacial Lake Agassiz Basin above Mahnomen.

Station Details

Mississippi River

Details of this station appear in Figure 2. The transect was first located on the upstream end of a small sandbar (Figure 3), but as water level declined, it was moved a few feet downstream in order to cross the sandbar point. Annual discharge at the station ranged between approximately 12 and 100 cfs. The bar became overgrown with *Scirpus fluviatilis* (Torr.) Gray and *Glyceria grandis* Wats..

Wild Rice River

This transect, established on the downstream end of a small island, was always above water except during floods (Figures 4 and 5). Annual discharge at the station ranged between approximately 17 and 200 cfs. *Populus deltoides* Marsh., *Cornus stolonifera* Michx., *Salix interior* Rowlee, and *S. fragilis* L. formed a vegetative cover on the island. Cattle pastures were situated on both stream banks, and a cattle feed lot was located 200 yards upstream.

Fig. 1.---The upper Mississippi and Wild Rice River basins.
● = study areas.

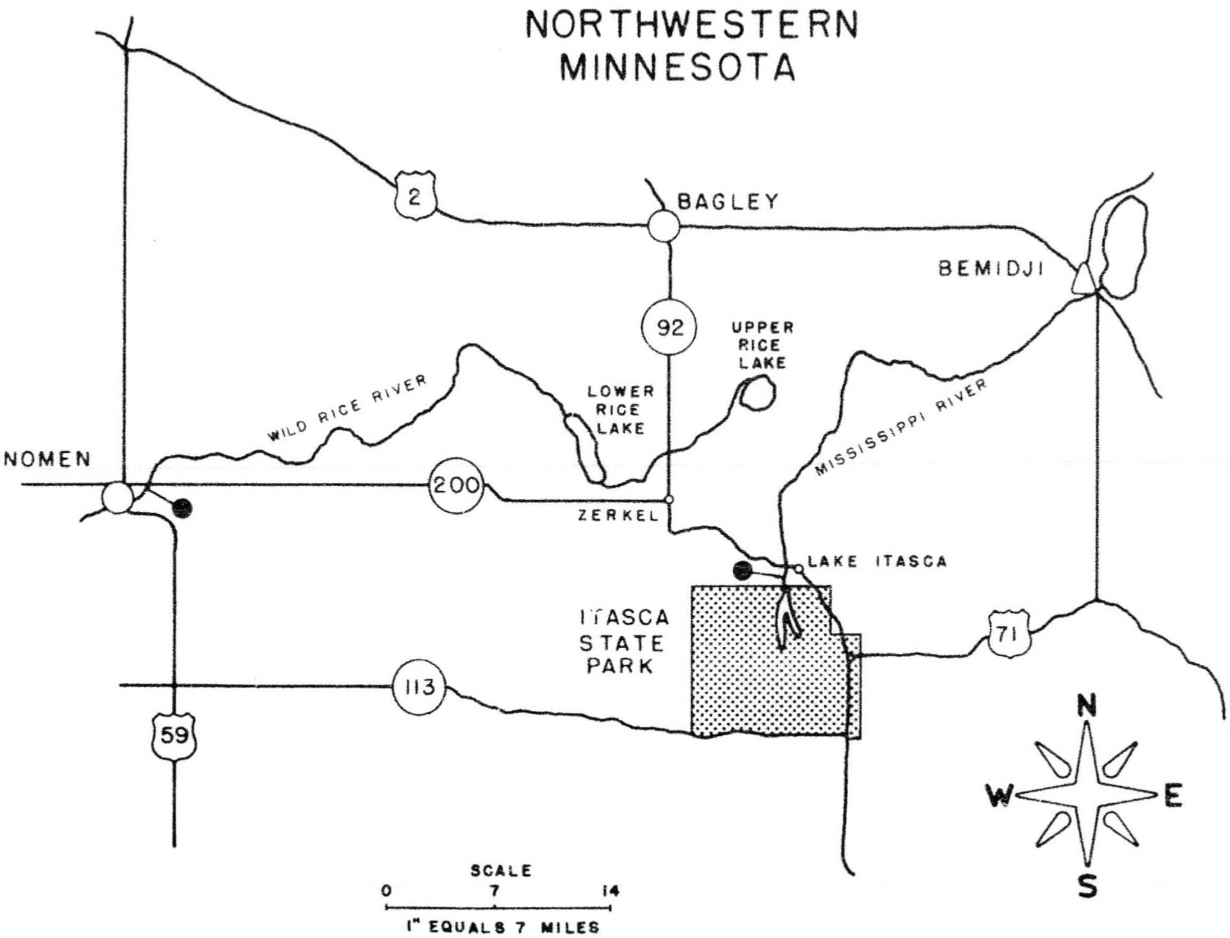

NORTHWESTERN
MINNESOTA
2
BAGLEY
BEMIDJI
92
UPPER
RICE
LAKE
LOWER
RICE
LAKE
WILD RICE RIVER
MISSISSIPPI RIVER
MAHNOMEN
200
ZERKEL
LAKE ITASCA
ITASCA
STATE
PARK
71
113
59
N
W
E
S
SCALE
0
7
14
1" EQUALS 7 MILES

Fig. 2.--The Mississippi River study area in autumn 1970. Transect 2 extended across stream just beyond the stranded log. Sand was usually exposed near stream margin to left.

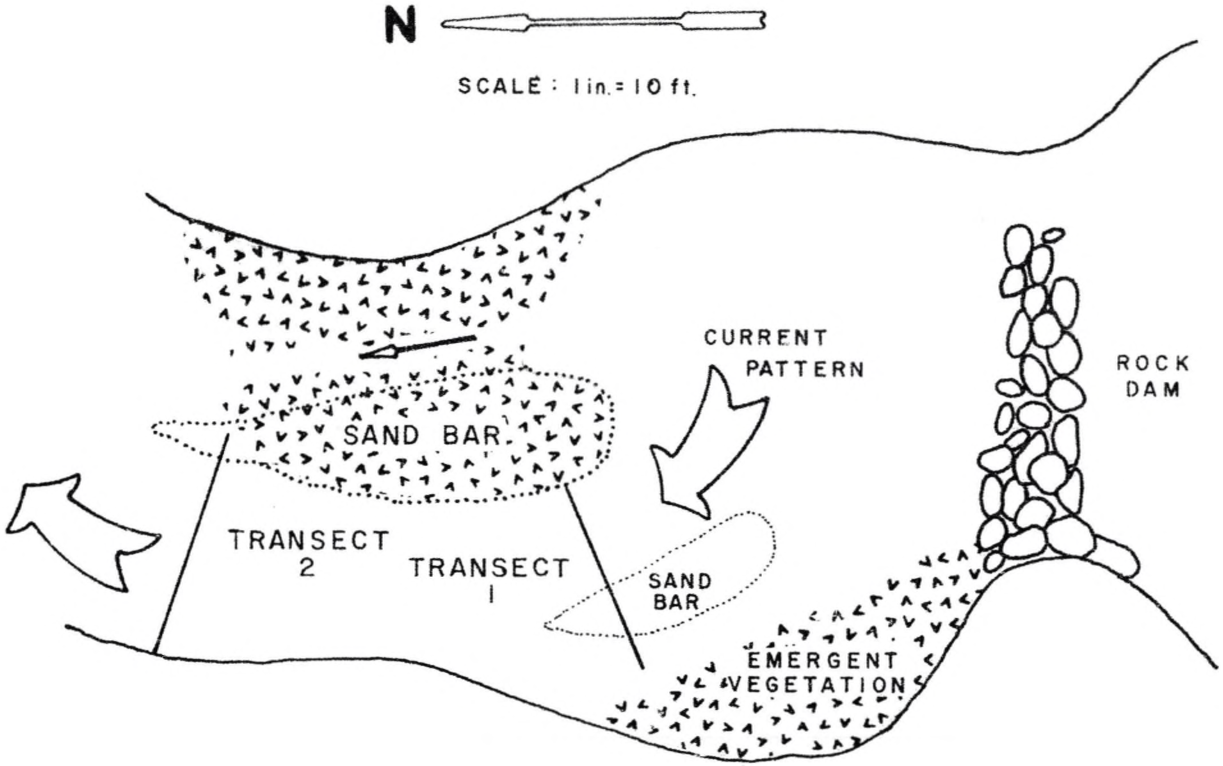


Fig. 3.--Mississippi River station details

Fig. 4.--The Wild Rice River station as seen from the left bank. The transect location is shown by a black line.

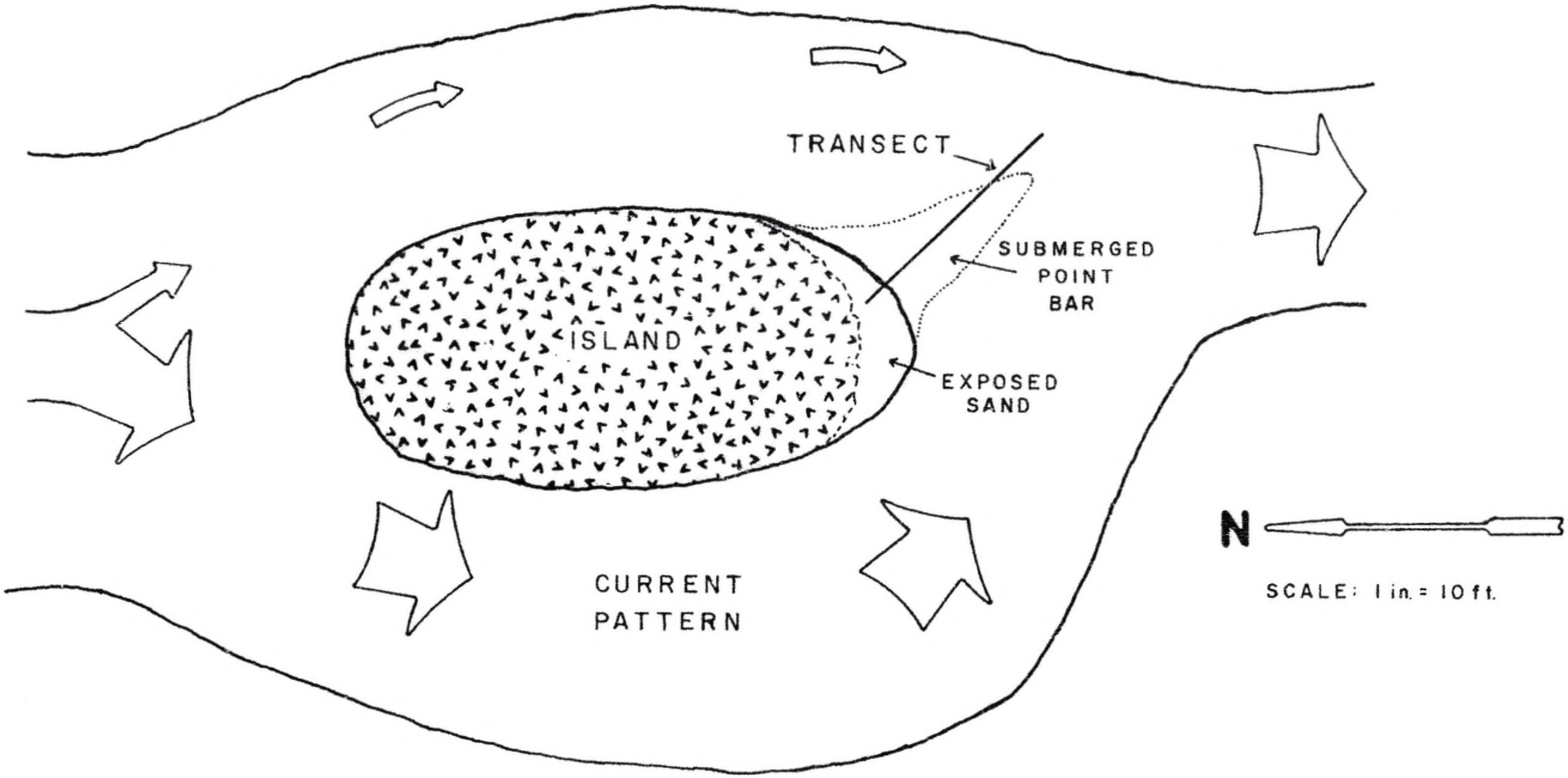


Fig. 5.—Wild Rice River station details

MATERIALS AND METHODS

Physical Features

Temperature

Temperature was taken at a depth of 5 cm in the sand, 6-7 cm above the bottom in water, and in shaded areas in the air, with a standardized laboratory thermometer.

Sand Grade Analysis

Samples obtained by thrusting brass tubes (with internal cross-sectional areas of 10 square centimeters) 6 cm into the sand, were shaken through a series of U. S. Standard Sieves of 4.76 mm (-2.25 phi), 0.149 mm (-1.00 phi), 0.595 mm (0.75 phi), 0.280 mm (2.00 phi), 0.149 mm (2.75 phi), and 0.074 mm (3.75 phi) mesh sizes. Horizontal patterns were generally based upon the entire 6 cm core and vertical ones upon one-centimeter core sections.

Miscellaneous

Capillarity was determined by measuring the height of water rise in dried, unsieved sand of the study area contained in glass tubes of 1.0 and 1.7 cm internal diameter.

Organic content was measured by ashing one-centimeter core sections at 450°C for 24 hours.

Pore space was determined by methods described by Pennak (1940).

Chemical Features

Sample Collection

Interstitial water was sampled with a device similar to that described by Neel (1948). Water was drawn into two bottles connected in series to the sampler. The smaller (60 ml), first bottle was used for oxygen, and the second (300 ml) for other analyses.

Samples above waterline were taken at depths ranging from 6 to 9 cm in the sand, while those from submerged sand were 4 to 6 cm deep. Stream water samples were taken from the surface.

Chemical Analyses

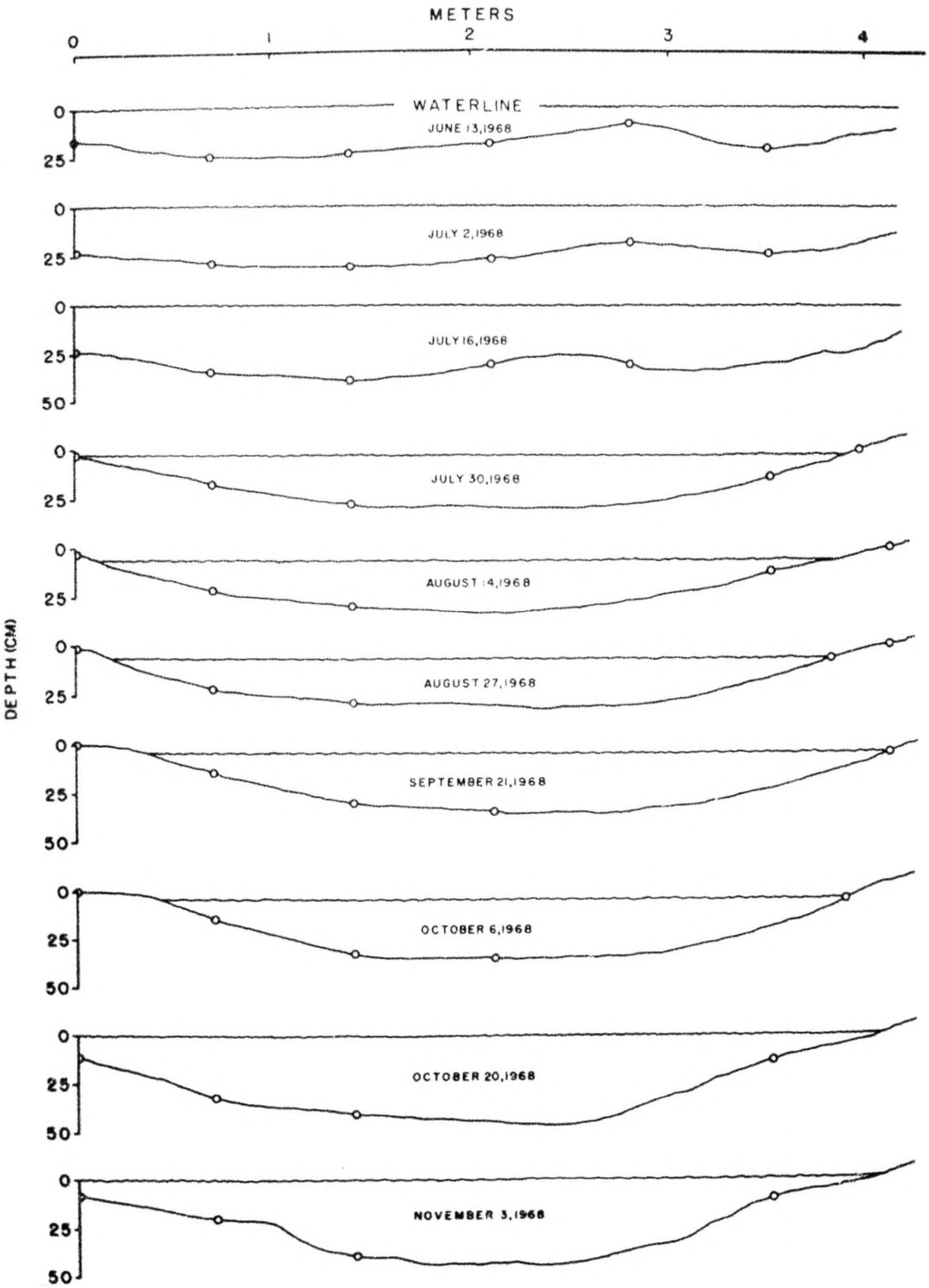
Oxygen, pH, alkalinity (carbonate and bicarbonate), total hardness, calcium, magnesium, orthophosphate, nitrite-nitrogen, and ammonia-nitrogen were determined according to the 12th edition of Standard Methods for the Examination of Water, Sewage, and Wastewater (American Public Health, et al., 1965). All analyses were performed in the field soon after collection.

Biological Features

Sampling Method

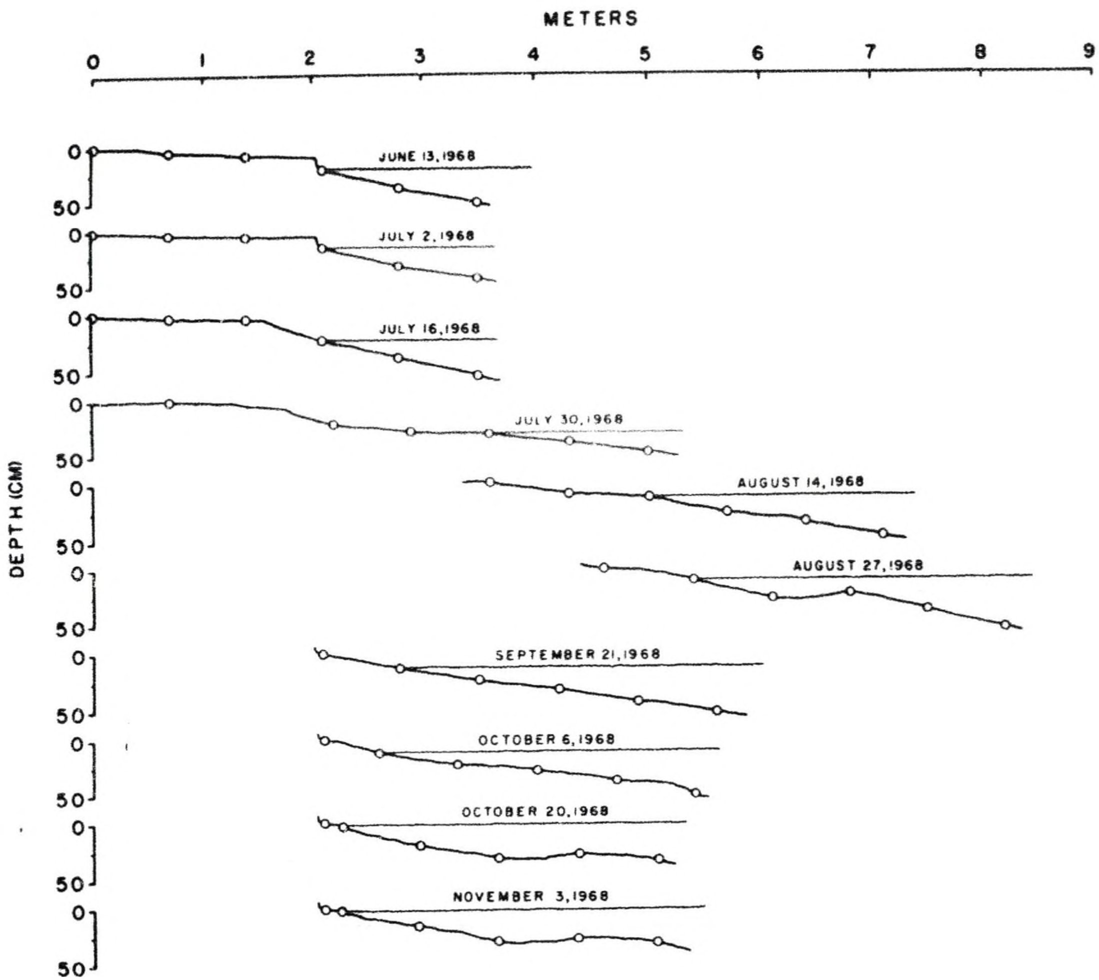
Sand samples for organismal study were taken along transects which were established so as to cross a variety of conditions existing in exposed and submerged sand. Sampling density was determined by these conditions. With regard to the Mississippi River: (1) all collections from Transect 1 represent the same relative positions (Figure 6); (2) Stations 1, 2, and 3 of Transect 2 were situated in the same area;

Fig. 6.--Fluctuations in water level, Mississippi River. June 13 - July 16, 1968 indicate Transect 1, other dates are for Transect 2. Circles indicate sampling sites.


METERS
0
1
2
3
4
WATERLINE
JUNE 13,1968
JULY 2,1968
JULY 16,1968
JULY 30,1968
AUGUST 14,1968
AUGUST 27,1968
SEPTEMBER 21,1968
OCTOBER 6,1968
OCTOBER 20,1968
NOVEMBER 3,1968
DEPTH (CM)
0
25
50

but (3) positioning of Stations 4 and 5 on Transect 2 was dependent upon the location of materials small enough to allow coring among coarser deposits along the left bank (Figure 6); and (4) the first three stations on both transects were in the same relative positions with respect to the sand bar, except that Transect 2 was approximately 3 m downstream. All sampling on the Wild Rice River was along the same transect, but stations were moved as dictated by conditions associated with falling water level. The water line served as a point of reference. Stations at it are called "0 cm", those above it are indicated by a "+" before the distance in centimeters, and those below it, by a "-" before the distance. Stations were usually spaced at 70 centimeter intervals, but there were some exceptions. On October 6 and 19, and November 3, stations were 50, 18, and 15 centimeters, respectively, from the waterline. With decreased discharge, the stations of June 13 were abandoned because of enroachment by vegetation. Movement of the sampled reach is shown in Figure 7. The sampling method used was similar to that described by Neel (1948). The brass core sampler was thrust into the sand, its upper end stoppered, the sampler with the core removed, and its lower end stoppered. Over-lying water was carefully pipetted off cores taken under water to minimize distrubance to upper sand layers. Cores were pushed to the tops of the tubes with a plunger and successive one-centimeter lengths cut off with a spatula. These sections were placed in small jars containing a saturated methol solution in which they remained 12 to 15 hours. Samples were then transferred to evaporating dishes where organisms were washed from the sand by stirring with an air jet. Three changes of water were normally used, and organisms were concentrated by centrifuging each wash. They were then preserved with

Fig. 7.--Fluctuations in water level, Wild Rice River. Circles indicate sampling sites.


METERS
0
1
2
3
4
5
6
7
8
9
DEPTH (CM)
0
50
JUNE 13,1968
JULY 2,1968
JULY 16,1968
JULY 30,1968
AUGUST 14,1968
AUGUST 27,1968
SEPTEMBER 21,1968
OCTOBER 6,1968
OCTOBER 20,1968
NOVEMBER 3,1968

5% formalin in a 40% glycerol solution.

Large quantities of silt and clay in Wild Rice samples and organic debris in Mississippi samples required reduction for accurate counts. This was accomplished with a separation technique: two milliliters of a well-mixed sample were diluted with distilled water and then gently placed atop a 25% glycerine solution contained in a separatory funnel. After about two hours, two fractions, one from the top and one from the bottom of the glycerine solution, were drawn off, centrifuged, and re-suspended in water. Samples were diluted according to amounts of debris still remaining prior to counting.

Counting Methods

Organisms were counted in a Sedgwick-Rafter cell at a magnification of 100 diameters. Three methods were employed: (1) the grid method, for groups exceeding 10,000 per counting cell; (2) the strip method, for those between 100 and 10,000 per cell; and (3) counts of the entire cell for groups containing less than 100 per cell. Concentration is expressed as number per cubic centimeter of sand. Thin mounts were made for identifications requiring higher magnification.

Live material was examined by a method described by F. E. Round of the University of Bristol, England (1970 oral personal communication). A one-centimeter core section was placed into a petri dish containing water, and covered for 24 hours with a cover slip. Organisms adhering could thus be examined microscopically. Identifications were according to: Leidy (1879), Hustedt (1930), Edmondson (1959), Prescott (1962), and Patrick and Reimer (1966).

Samples were collected weekly from June 13, 1968 through

September 3, 1968, and bimonthly from September 21, 1968 through November 3, 1968 (about the time of freeze-up). A total of 700 samples were analyzed, which provided a bimonthly frequency.

RESULTS

Physical Features

Temperature

Temperature changes in exposed and submerged sand lagged behind those of stream and air (Table 1). Response to rain is shown by July 30 data for the Wild Rice River, and effects of air temperature drop may be noted in Mississippi River records of August 14, which followed four nights with temperatures of 10°C or below.

Sand Analysis

Mississippi River

Terminology referring to grades of sand and other materials appears in Table 2. Grade composition of the upper six centimeters of sand (Figures 8, 9, and 10) shows that: (1) the sand of the original sampling transect was eroded by currents at the second and third stations, and received deposition at areas represented by the first, fourth, fifth, and sixth stations; (2) erosion occurred to some degree at all sites except at Station 1 on the second transect, as water level declined; and (3) increased discharge maintained erosion except at Station 2 on November 3 when deposition occurred. Erosion was indicated by coarser grades of sand and gravel, and deposition by finer grades.

Station 2 showed a bi-modal occurrence of coarse and medium sand

TABLE 1

TEMPERATURE READINGS FOR THE MISSISSIPPI AND WILD RICE RIVERS (°C), JUNE - NOVEMBER, 1968

River	Region	Sampling Date															
		6/13	6/24	7/2	7/8	7/16	7/23	7/30	8/6	8/14	8/20	8/27	9/3	9/22	10/6	10/20	11/3
Mississippi	Air	12*	17	25*	21.5	25	22	19*	30.5	11	23.5	22	15*	14*	18	11	10
	Str.	18	20	18.5	24	26	24.5	20.5	27	17	23.5	20	17	17	12	10	6
	S.S.	17	19	17.5	23	25	24	20.5	25	18	22	19	17	16	12	9	6
	E.S.	--	-	-	-	-	-	20	29	12	21	19	16	15	11	-	-
Wild Rice	Air	17*	19	12.5*	17*	25*	20	18*	23	15	17	18	15*	18*	9	4.5	9
	Str.	16	19	14	22	24	20.5*	18	23	17	17	15	15	16.5	7	5	4
	S.S.	16	18	13	21	23	20.5	18	23	17	17	16	16	16	7.5	5	4
	E.S.	15	17	13	20.5	22	19	18	22	24	15	13.5	15	19	8.5	5	5

Notes: Str. = Stream
S.S. = Submerged Sand
E. S.= Exposed Sand
* = Rain

Fig. 8.--Horizontal variation in grade of the upper 6 centimeters of sand, Transect 1, Mississippi River, June 13, 1968.

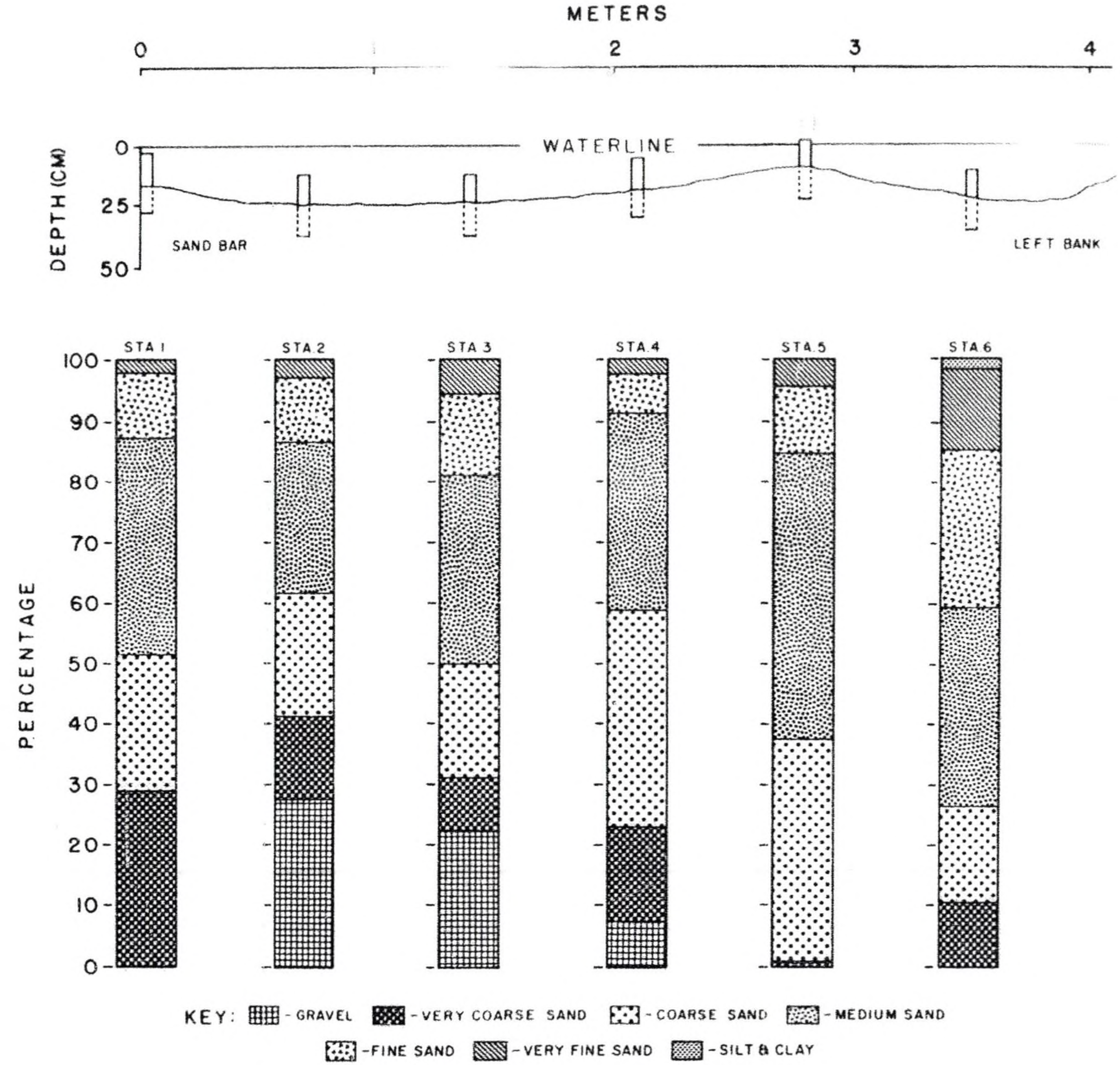
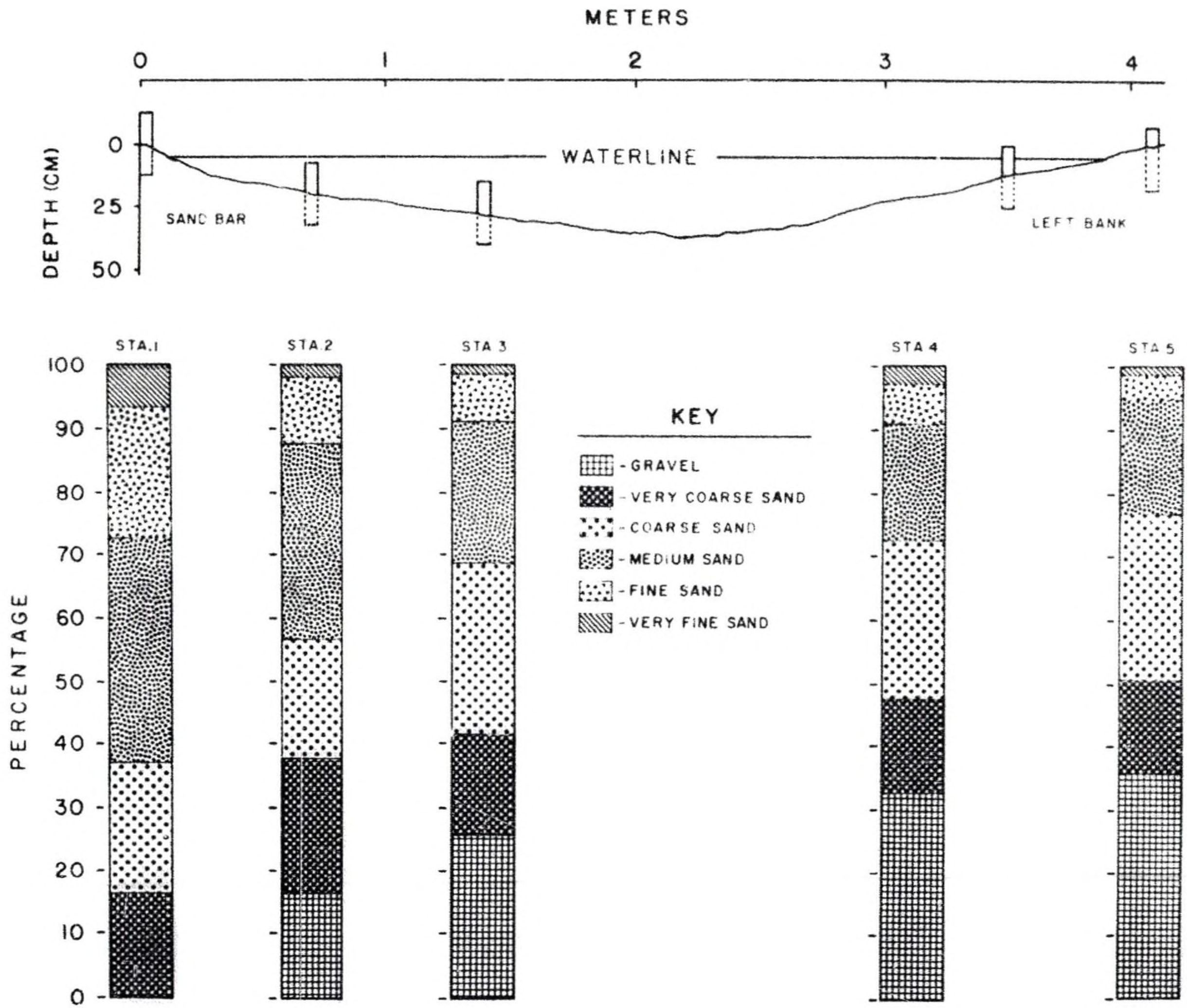

METERS
0
2
3
4
WATERLINE
DEPTH (CM)
0
25
50
SAND BAR
LEFT BANK
STA 1
STA 2
STA 3
STA 4
STA 5
STA 6
PERCENTAGE
100
90
80
70
60
50
40
30
20
10
0
KEY:
- GRAVEL
- VERY COARSE SAND
- COARSE SAND
- MEDIUM SAND
- FINE SAND
- VERY FINE SAND
- SILT & CLAY

Fig. 9.—Horizontal variation in grade of the upper 6 centimeters of sand, Transect 2, Mississippi River, August 14, 1968.



METERS
0
1
2
3
4
DEPTH (CM)
0
25
50
WATERLINE
SAND BAR
LEFT BANK
PERCENTAGE
100
90
80
70
60
50
40
30
20
10
0
STA.1
STA.2
STA.3
STA.4
STA.5
KEY
- GRAVEL
- VERY COARSE SAND
- COARSE SAND
- MEDIUM SAND
- FINE SAND
- VERY FINE SAND

Fig. 10.--Horizontal variation in grade of the upper 6 centimeters of sand, Transect 2, Mississippi River, November 3, 1968.

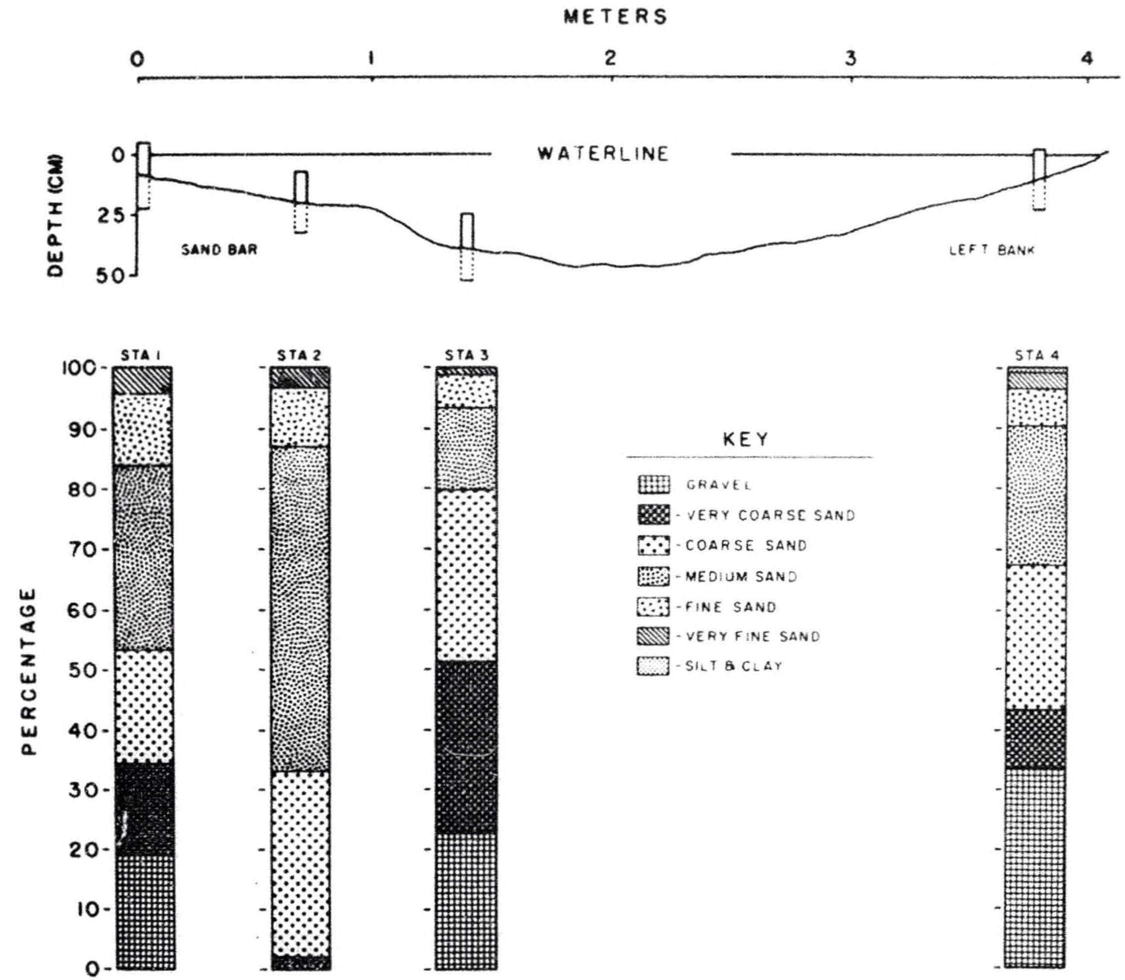

METERS
0
1
2
3
4
DEPTH (CM)
0
25
50
WATERLINE
SAND BAR
LEFT BANK
STA 1
STA 2
STA 3
STA 4
PERCENTAGE
100
90
80
70
60
50
40
30
20
10
0
KEY
GRAVEL
- VERY COARSE SAND
- COARSE SAND
- MEDIUM SAND
- FINE SAND
- VERY FINE SAND
- SILT & CLAY

TABLE 2

EQUIVALENTS FOR SEDIMENT ANALYSES
AS USED IN FIGURES AND TEXT

Common Term	Material Retained on U. S. Standard Sieve (in mm)	phi Equivalent
Gravel	4.76	-2.25
Very Coarse Sand	2.0	-1
Coarse Sand	0.595	0.75
Medium Sand	0.280	2.0
Fine Sand	0.149	2.75
Very Fine Sand	0.074	3.75
Silt and Clay	Pan	3.75

in the upper three centimeters (Figure 11). The fourth centimeter represented the former first centimeter of sand, which still retained effects of the lower flow regime having higher percentages of fine sand. Sand generally became finer with depth (Figure 12). At Stations 4 and 5 current removed finer materials and left increased percentages of gravel and coarse sand in the upper layers.

Wild Rice River

On June 13, fine and very fine sands were the most abundant materials above and below waterline (Figure 13). Medium sand was the coarsest grade found, and silt was a noticeable component of each core. Weak currents determined the position of deposition and erosion of the

Fig. 11.--Vertical variation in sand grade, station 2, Transect 2, Mississippi River, November 3, 1968. The upper 3 centimeters were newly deposited sand.

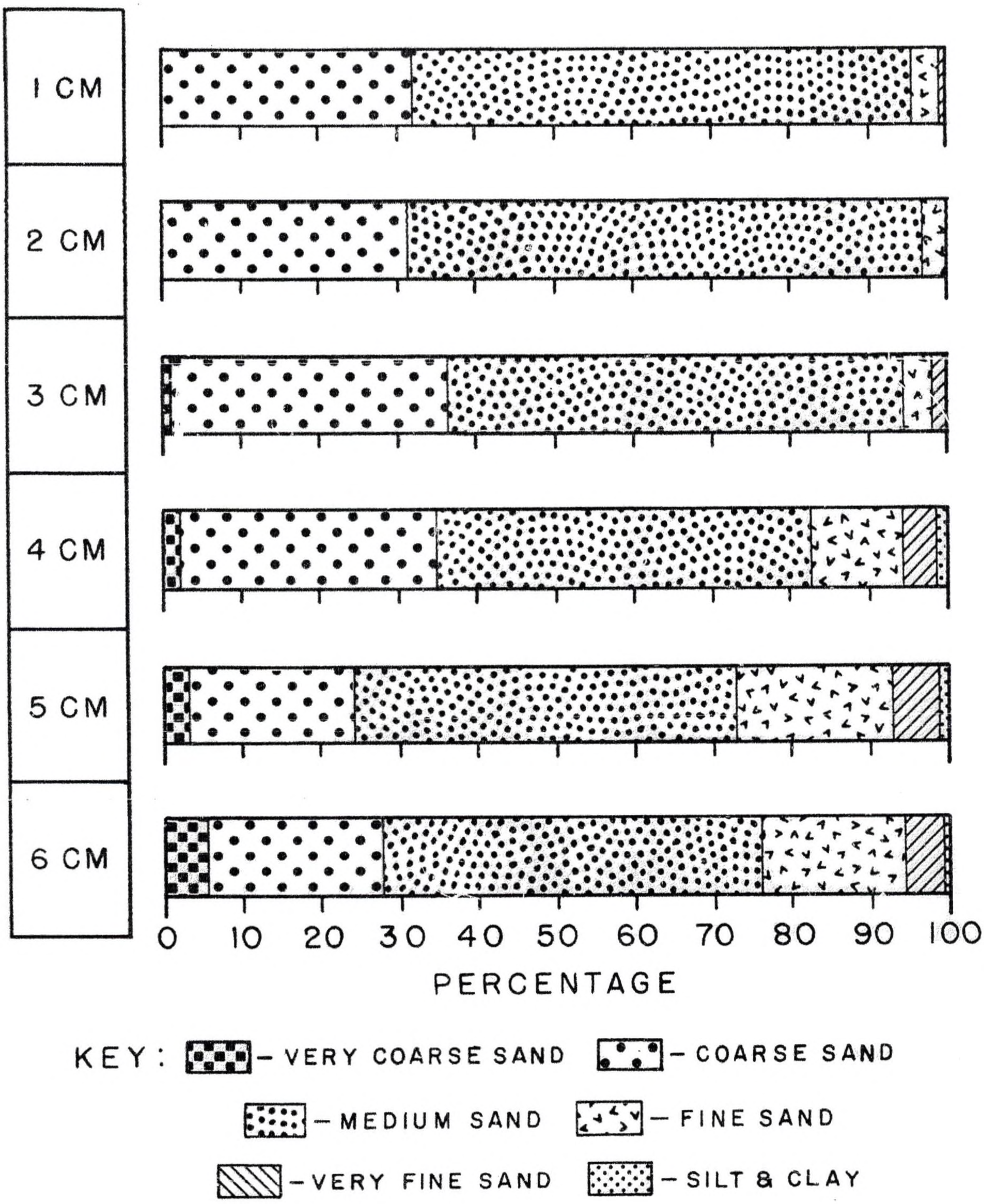

1 CM
2 CM
3 CM
4 CM
5 CM
6 CM
0 10 20 30 40 50 60 70 80 90 100
PERCENTAGE
KEY:
– VERY COARSE SAND
– COARSE SAND
– MEDIUM SAND
– FINE SAND
– VERY FINE SAND
– SILT & CLAY

Fig. 12.--Vertical variation in sand grade, Transect 2, Mississippi River, September 21, 1968.

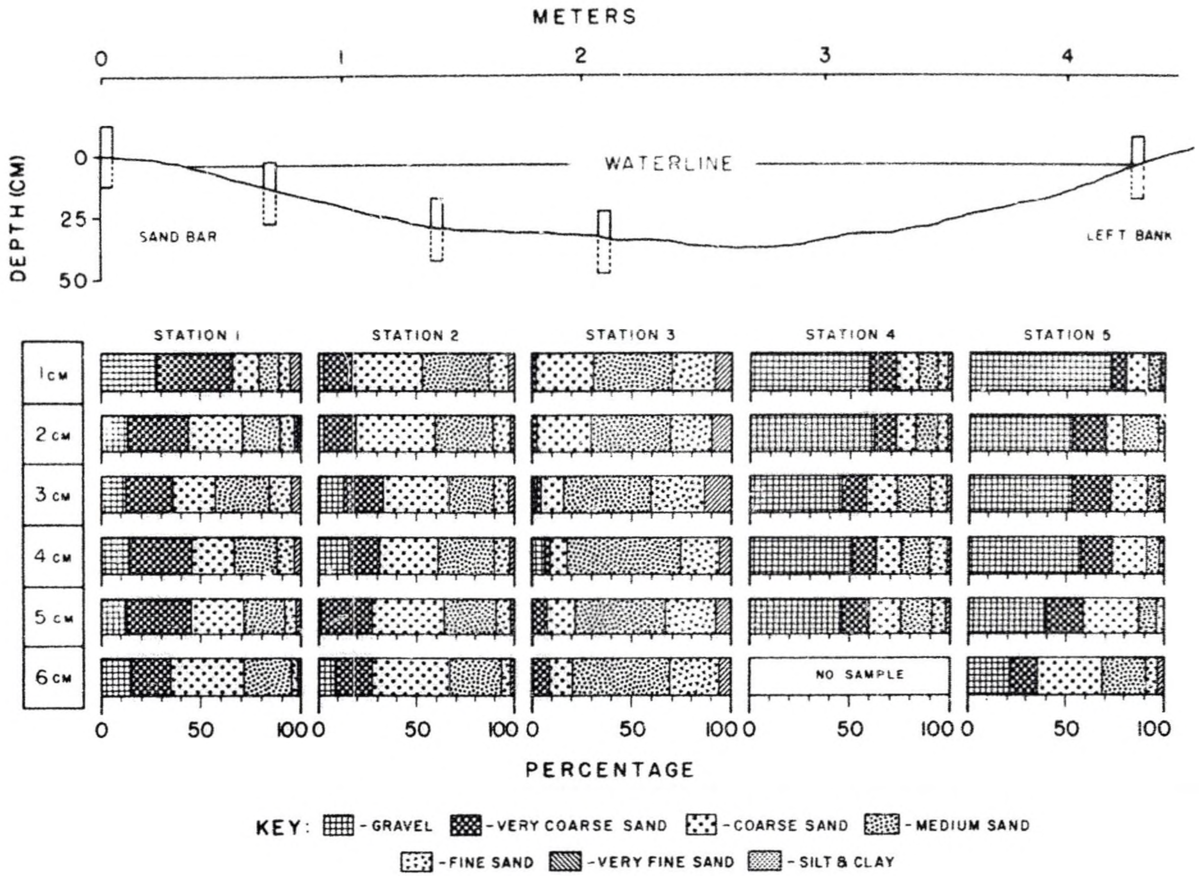
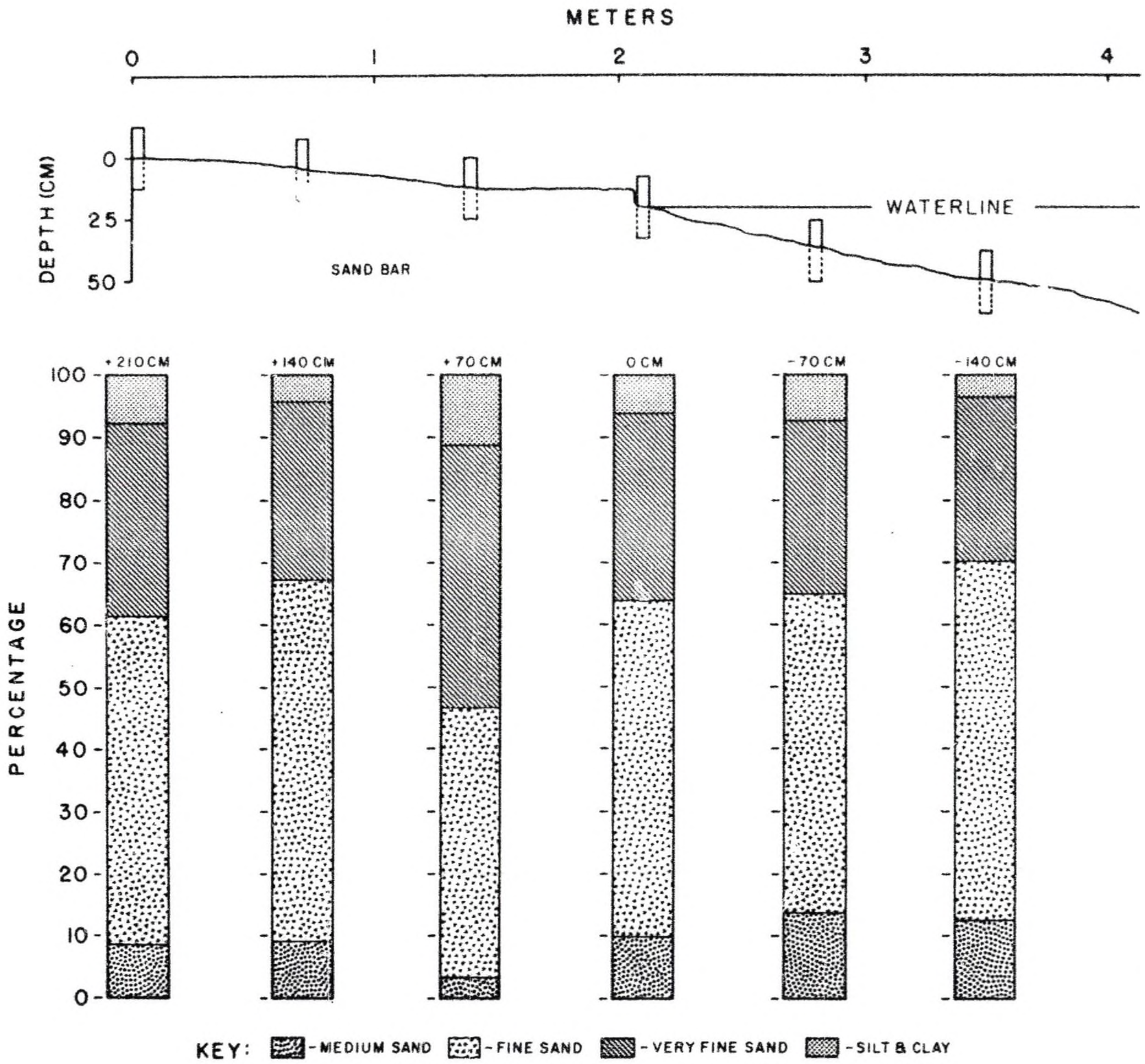

METERS
0
1
2
3
4
DEPTH (CM)
0
25
50
WATERLINE
SAND BAR
LEFT BANK
STATION 1
STATION 2
STATION 3
STATION 4
STATION 5
1 CM
2 CM
3 CM
4 CM
5 CM
6 CM
NO SAMPLE
0
50
100
PERCENTAGE
KEY: - GRAVEL - VERY COARSE SAND - COARSE SAND - MEDIUM SAND
- FINE SAND - VERY FINE SAND - SILT & CLAY

Fig. 13.—Horizontal variation in grade of the upper 6 centimeters of sand, Wild Rice River, June 13, 1968.


METERS
0
1
2
3
4
DEPTH (CM)
0
25
50
SAND BAR
WATERLINE
+210 CM
+140 CM
+70 CM
0 CM
-70 CM
-140 CM
PERCENTAGE
100
90
80
70
60
50
40
30
20
10
0
KEY:
- MEDIUM SAND
- FINE SAND
- VERY FINE SAND
- SILT & CLAY

submerged portion of the transect (Figure 14a).

By August 14, water level decline had exposed an additional 2.8 m of beach. The sampling site that had been 140 cm below the waterline on June 13 was now 140 cm above it. Decreased discharge and downbeach movement of the waterline resulted in an increase of medium and coarse sands (Figure 15). The upper beach was composed mainly of fine and very fine sand, but medium sand increased and silt decreased toward the waterline. Erosion removed finer grades at the waterline. Erosion was also indicated by coarser grades at 70 and 210 cm below the waterline. Higher percentages of finer grades suggested that deposition occurred 140 cm below waterline. This grade variation in submerged sand was the result of current patterns noted on August 14 (Figure 14b). The major current along the right bank produced eddies toward the point of the island, which induced erosion at -70 and -210 cm stations, and deposition at the -140 station.

Increased discharge in autumn raised the water level to within 15 centimeters of its June 13 position, and the grade distribution of sand then was similar to that of June 13, with fine and very fine sand predominating (Figure 16). Greater amounts of coarser grades evidently arose from small currents arising in the left channel. (Figure 14c)

Sand became coarser with depth except for the +70 cm and the -210 cm stations (Figure 17). The other stations on September 21 indicate that deposition was occurring, by increased percentages of the finer grades in the upper layers. The increased percentage of finer grades with depth in the 70 cm and -210 cm stations gives insight into past deposition.

Fig. 14.--Current pattern variation with changing water level, Wild Rice River, 1968. Transects 4 meters long.

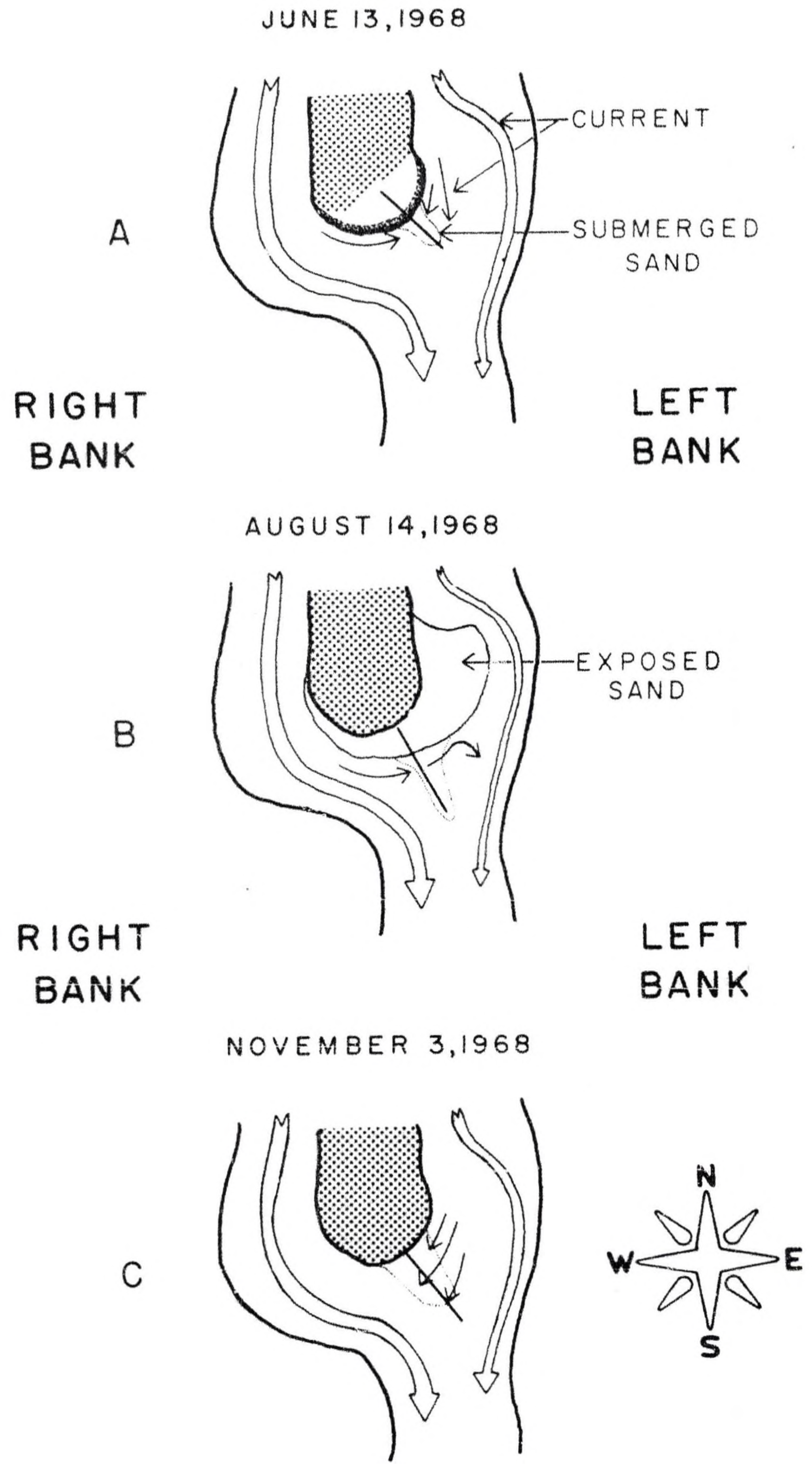

JUNE 13, 1968
CURRENT
SUBMERGED SAND
A
RIGHT BANK
LEFT BANK
AUGUST 14, 1968
EXPOSED SAND
B
RIGHT BANK
LEFT BANK
NOVEMBER 3, 1968
C
N
W
E
S

Fig. 15.--Horizontal variation in grade of the upper 6 centimeters of sand, Wild Rice River, August 14, 1968.

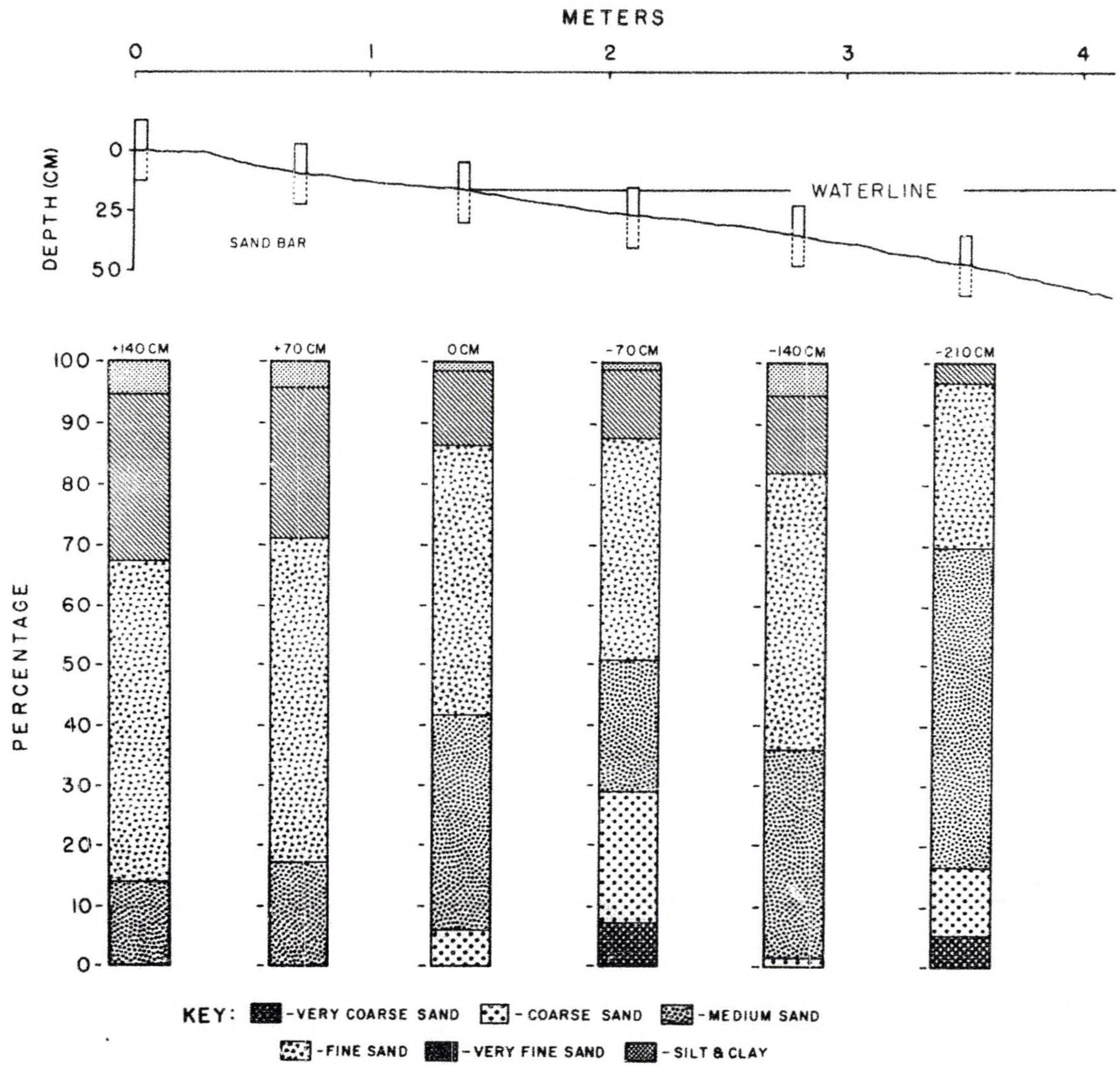
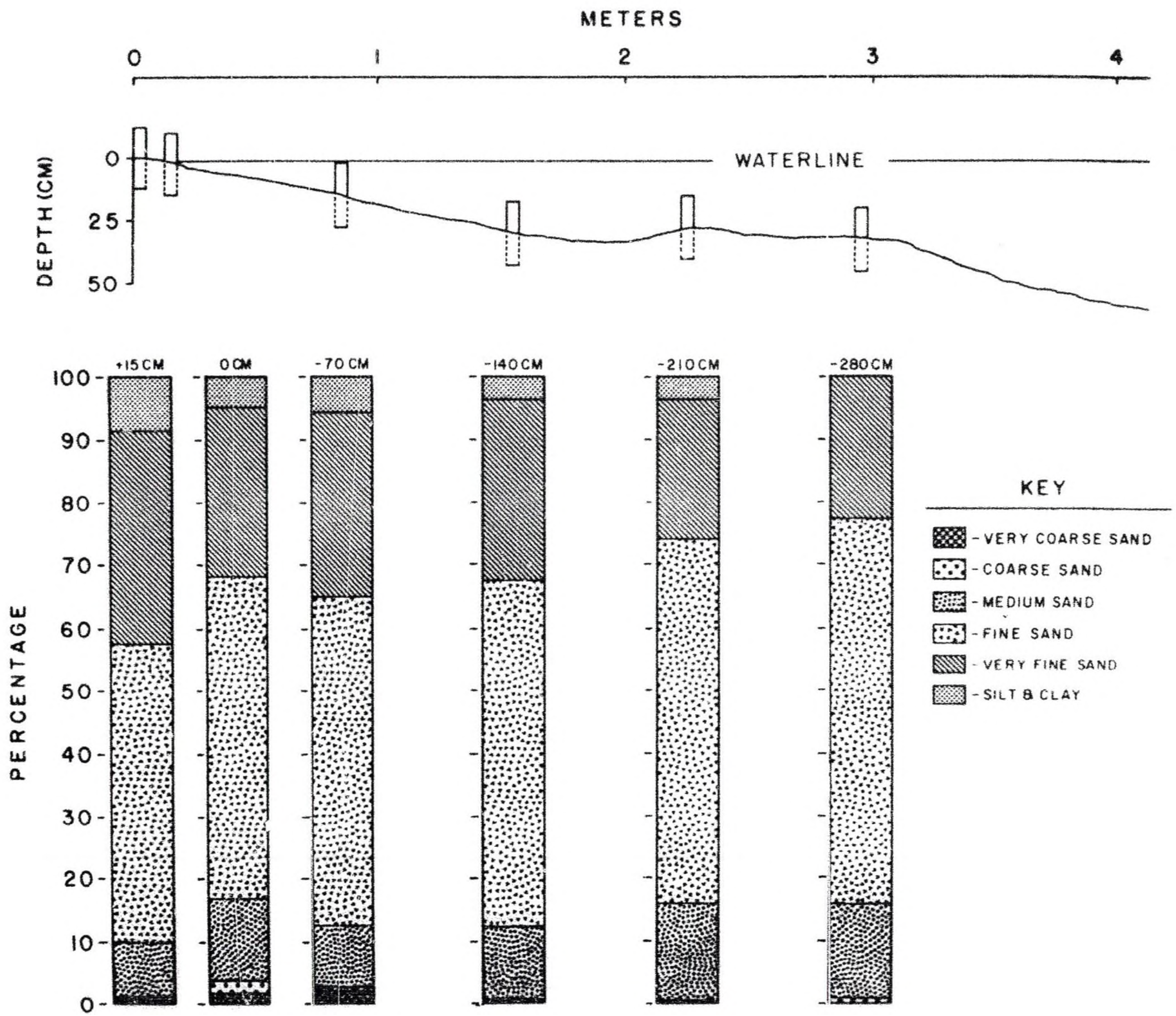
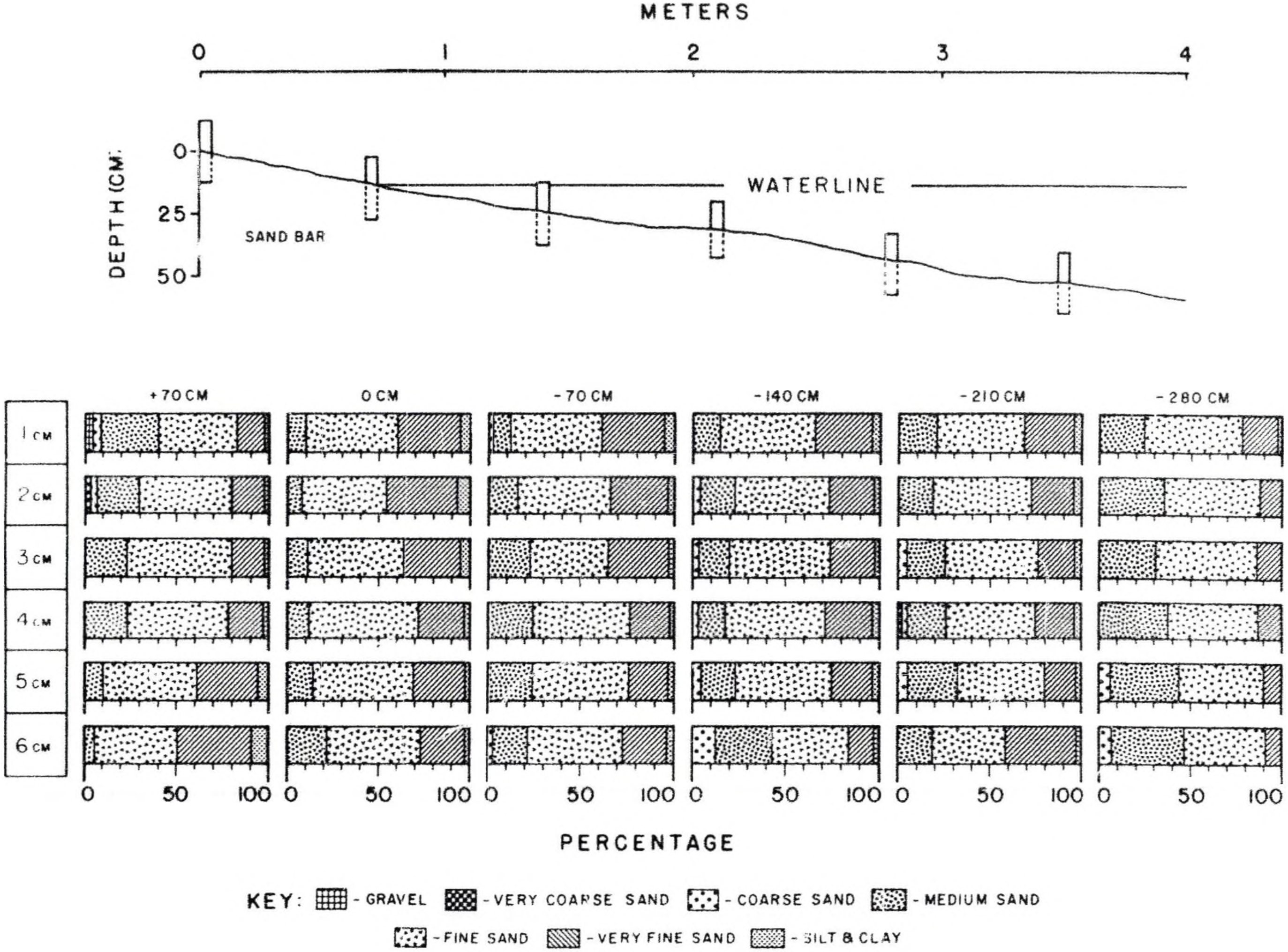

METERS
0
1
2
3
4
DEPTH (CM)
0
25
50
WATERLINE
SAND BAR
+140 CM
+70 CM
0 CM
-70 CM
-140 CM
-210 CM
PERCENTAGE
100
90
80
70
60
50
40
30
20
10
0
KEY: -VERY COARSE SAND -COARSE SAND -MEDIUM SAND
-FINE SAND -VERY FINE SAND -SILT & CLAY

Fig. 16.--Horizontal variation in grade of the upper 6 centimeters of sand, Wild Rice River, November 3, 1968.



METERS
0
1
2
3
4
DEPTH (CM)
0
25
50
WATERLINE
PERCENTAGE
100
90
80
70
60
50
40
30
20
10
0
+15 CM
0 CM
-70 CM
-140 CM
-210 CM
-280 CM
KEY
- VERY COARSE SAND
- COARSE SAND
- MEDIUM SAND
- FINE SAND
- VERY FINE SAND
- SILT & CLAY

Fig. 17.--Vertical variation in sand grade, Wild Rice River, September 21, 1968.


METERS
0
1
2
3
4
DEPTH (CM)
0
25
50
WATERLINE
SAND BAR
+70 CM
0 CM
-70 CM
-140 CM
-210 CM
-280 CM
1 cm
2 cm
3 cm
4 cm
5 cm
6 cm
0
50
100
PERCENTAGE
KEY: - GRAVEL - VERY COARSE SAND - COARSE SAND - MEDIUM SAND
- FINE SAND - VERY FINE SAND - SILT & CLAY

Capillarity

Mississippi River

Height to which water rose in beaches above the waterline was a function of capillarity (Table 3 and Figure 9). Finer sands and

TABLE 3

CAPILLARITY FOR MISSISSIPPI RIVER AS DETERMINED FROM JUNE 13, 1968 TRANSECT

Core	Location of Core From Edge of Submerged sandbar (cm)	Height Water Ascended in Column (mm)
1	0	36
2	70	48
3	140	45
4	210	47
5	280	54
6	350	80

organic debris at Station 6 supported a capillary rise of 80 mm, whereas coarser materials at Station 1 gave only a 36 mm rise. Intermediate sand types gave intermediate values.

Wild Rice River

Finer sediments here gave a capillary rise of 191 mm (Figure 13 and Table 4), and the lowest value obtained (118 mm) surpassed the highest values for the Mississippi River area.

TABLE 4

CAPILLARITY FOR WILD RICE RIVER AS DETERMINED FROM JUNE 13, 1968 TRANSECT

Core	Location of Core From Waterline (cm)	Height Water Ascended in Column (mm)
1	+210	167
2	+140	188
3	+ 70	191
4	0	182
5	- 70	167
6	-140	118

Organic Content

Mississippi River

Organic determinations of 1969 samples (Table 5) showed highest content in the surface layers of the sand (217.4 mg/10cc sand).

Wild Rice River

Organic determinations of exposed and submerged sand samples showed both having highest content in the surface layers: 191.0 mg/10 cc and 377.1 mg/10 cc of sand, respectively (Table 5). Stabilized conditions existing with exposed sand allowed reduction of organic materials to occur with depth. Fluctuation between deposition and erosion of the submerged sand accounts for the variation in depth distribution of

TABLE 5

VERTICAL VARIATION IN ORGANIC CONTENT OF THE MISSISSIPPI AND WILD RICE RIVER PSAMMON, OCTOBER 18, 1969; MILLIGRAMS PER 10 CUBIC CENTIMETERS OF SAND

Depth (cm)	Mississippi River Submerged Sand	Wild Rice River with Reference to Waterline	
		Exposed Sand (+70 cm)	Submerged Sand (-70 cm)
1	217.4	191.0	377.1
2	165.8	182.0	187.2
3	138.0	149.4	157.0
4	144.9	163.3	216.1
5	187.7	159.4	165.9
6	105.5	94.5	225.2

organic matter.

Water Level Fluctuation

Mississippi River

Seasonal fluctuations in water level are presented in Figure 6. Circles along the stream profiles represent positions of cores on these dates. Profiles from June 13 through July 16 represent changes that occurred at Transect 1, whereas remaining profiles illustrate Transect 2 (Figure 3). The move was made because sand was emerging from water on the point bar and left bank as discharge decreased. Two inches of rain from October 16 through October 18 again submerged the exposed regions.

Wild Rice River

Changes in waterline, transect profile, and core placement appear in Figure 7. Profiles are situated so as to represent their location and change with respect to the conditions found on June 13. Sampling was moved down the slope after vegetation covered older areas of exposed beach.

Pore Space

Ungraded sand samples yielded the following percentage pore space: 22% to 25% for the Mississippi River, and 35% to 37% for the Wild Rice River.

Chemical Features

Mississippi River

Oxygen

Oxygen was present in submerged sand during the first weeks of study (Table 6a). Exposed sand contained oxygen on two days only: during a rain on July 30, and early on the morning of August 14, which was preceded by several days of cool temperatures.

Hydrogen Ion Concentration

Submerged and exposed sand were consistently lower in pH than the stream, and exposed sand was lower than that under water on all dates (Table 6a).

TABLE 6

CHEMICAL FEATURES OF INTERSTITIAL AND STREAM WATER EXCEPT FOR pH, VALUES ARE MILLIGRAMS PER LITER

A. Mississippi River

Date	Position	Chemical Determinations									
		pH	O_2	CO_3	HCO_3	T.H.	Ca	Mg	PO_4	NH_4-N	NO_2-N
June 13	Str.	7.9	8.6	18	135	187	99	88	. .	. .	. .
	S.S.	6.6	0.0	0.0	220	235	176	99	. .	. .	. .
	E.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	. .	. .	. .
June 24	Str.	7.85	8.8	20	134	165	88	77	. .	. .	. .
	S.S.	7.2	4.4	0.0	166	187	94	93	. .	. .	. .
	E.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	. .	. .	. .
July 2	Str.	7.8	8.8	28	134	187	99	88	. .	. .	. .
	S.S.	6.7	1.2	0.0	192	242	121	121	. .	. .	. .
	E.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	. .	. .	. .
July 8	Str.	8.0	10.4	16	144	165	55	110	. .	. .	. .
	S.S.	6.8	1.6	0.0	210	220	88	132	. .	. .	. .
	E.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	. .	. .	. .
July 16	Str.	7.85	7.6	20	126	143	55	88	. .	. .	. .
	S.S.	6.75	2.4	0.0	156	198	77	121	. .	. .	. .
	E.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	. .	. .	. .
July 23	Str.	8.0	8.8	32	114	143	60	83	. .	. .	. .
	S.S.	6.75	2.4	0.0	141	204	77	127	. .	. .	. .
	E.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	. .	. .	. .
July 30	Str.	7.45	6.0	16	138	165	94	71	. .	. .	. .
	S.S.	6.8	3.0	0.0	163	176	110	66	. .	. .	. .
	E.S.	6.65	0.6	0.0	150	160	88	72	. .	. .	. .
Aug. 6	Str.	8.25	8.0	36	108	154	77	77	. .	. .	. .
	S.S.	7.1	0.0	0.0	150	154	99	55	. .	. .	. .
	E.S.	7.0	0.0	0.0	154	154	88	66	. .	. .	. .
Aug. 14	Str.	7.5	6.4	16	126	143	77	66	N.S.	N.S.	N.S.
	S.S.	7.1	1.5	0.0	154	148	82	66	0.25	0.7	0.0
	E.S.	6.9	1.6	0.0	152	143	77	66	1.62	0.45	0.0
Aug. 20	Str.	8.25	8.0	20	119	154	77	77	N.S.	N.S.	N.S.
	S.S.	7.25	2.0	0.0	152	154	77	77	0.92	0.6	0.0
	E.S.	7.0	0.0	0.0	152	165	77	88	1.62	0.6	0.0
Aug. 27	Str.	8.25	8.0	20	132	154	88	66	. .	. .	. .
	S.S.	7.15	0.0	0.0	196	198	132	66	. .	. .	. .
	E.S.	6.95	0.0	0.0	210	242	143	99	. .	. .	. .
Sept. 3	Str.	7.4	6.5	12	138	165	88	77	. .	. .	. .
	S.S.	7.0	0.0	0.0	214	220	120	100	. .	. .	. .
	E.S.	7.1	0.0	0.0	222	242	143	99	. .	. .	. .
Sept. 21	Str.	7.55	7.2	12	144	187	88	99	0.0	1.0	0.0
	S.S.	7.15	0.0	0.0	168	231	99	132	0.0	2.0	0.0
	E.S.	7.0	0.0	0.0	232	275	198	77	0.32	0.45	0.0
Oct. 6	Str.	7.9	9.2	12	146	187	99	88	0.0	0.0	0.0
	S.S.	7.05	0.0	0.0	224	242	154	88	0.97	0.7	0.0
	E.S.	6.9	0.0	0.0	240	275	176	99	0.0	0.0	0.0
Oct. 19	Str.	8.0	11.2	8	150	165	88	77	0.0	0.3	0.0
	S.S.	7.3	0.0	0.0	234	286	143	143	0.97	1.1	0.0
	E.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Nov. 3	Str.	8.1	11.2	16	140	165	88	77	0.97	0.0	0.0
	S.S.	7.4	0.0	0.0	20[illegible]	231	154	77	2.6	0.5	0.0
	E.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

B. Wild Rice River

	Str.	7.4	6.8	24	188	275	165	110	. .	. .	. .

TABLE 6 - Continued

B. Wild Rice River

Date	Position	Chemical Determinations									
		pH	O_2	CO_3	HCO_3	T.H.	Ca	Mg	PO_4	NH_4-N	NO_2-N
June 13	Str.	7.4	6.8	24	188	275	165	110	. .	. .	. .
	S.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	. .	. .	. .
	E.S.	6.5	A.E.	0.0	270	330	187	143	. .	. .	. .
June 24	Str.	7.7	6.8	12	174	220	121	99	. .	. .	. .
	S.S.	6.9	0.0	0.0	250	275	176	99	. .	. .	. .
	E.S.	7.1	0.0	0.0	546	539	352	187	. .	. .	. .
July 2	Str.	8.0	8.0	20	166	220	121	99	. .	. .	. .
	S.S.	7.0	0.0	0.0	186	A.E.	143	A.E.	. .	. .	. .
	E.S.	6.85	0.0	0.0	574	682	396	286	. .	. .	. .
July 8	Str.	7.6	6.0	20	166	220	121	99	. .	. .	. .
	S.S.	6.55	0.0	0.0	315	401	209	191	. .	. .	. .
	E.S.	6.6	0.0	0.0	324	407	198	209	. .	. .	. .
July 16	Str.	7.3	6.0	20	158	198	99	99	. .	. .	. .
	S.S.	6.55	0.0	0.0	222	231	143	88	. .	. .	. .
	E.S.	6.5	0.0	0.0	394	473	280	193	. .	. .	. .
July 23	Str.	7.6	6.0	16	176	189	99	90	. .	. .	. .
	S.S.	6.6	0.0	0.0	230	242	132	110	. .	. .	. .
	E.S.	6.5	0.0	0.0	310	330	187	143	. .	. .	. .
July 30	Str.	7.6	7.0	24	164	200	127	73	. .	. .	. .
	S.S.	6.7	0.0	0.0	260	264	165	99	. .	. .	. .
	E.S.	6.4	0.0	0.0	260	253	176	77	. .	. .	. .
Aug. 6	Str.	7.7	6.0	22	162	204	116	88	. .	. .	. .
	S.S.	6.85	0.0	0.0	326	275	209	66	. .	. .	. .
	E.S.	6.65	0.0	0.0	264	231	176	55	. .	. .	. .
Aug. 14	Str.	8.2	8.8	32	160	209	121	88	N.S.	N.S.	N.S.
	S.S.	7.2	0.0	0.0	230	231	192	39	0.0	3.5	0.0
	E.S.	7.1	0.0	0.0	264	264	154	110	0.0	3.5	0.0
Aug. 20	Str.	7.55	5.6	20	166	220	110	110	N.S.	N.S.	N.S.
	S.S.	6.9	0.0	0.0	268	253	187	66	5.84	4.0	0.0
	E.S.	6.85	0.0	0.0	270	297	154	143	4.54	4.0	0.0
Aug. 27	Str.	7.6	8.0	20	170	220	121	99	. .	. .	. .
	S.S.	6.9	0.0	0.0	248	309	165	144	. .	. .	. .
	E.S.	6.6	0.0	0.0	296	264	176	88	. .	. .	. .
Sept. 3	Str.	7.85	8.0	20	168	220	121	99	. .	. .	. .
	S.S.	6.95	0.0	0.0	252	209	165	44	. .	. .	. .
	E.S.	6.85	0.0	0.0	292	242	176	66	. .	. .	. .
Sept. 21	Str.	8.65	7.6	16	176	210	121	89	0.64	0.45	0.0
	S.S.	7.1	0.0	0.0	224	319	132	187	2.27	3.0	0.0
	E.S.	6.85	0.0	0.0	344	330	220	110	3.24	5.0	0.0
Oct. 6	Str.	7.9	11.6	14	165	220	132	88	0.0	0.0	0.0
	S.S.	7.0	0.0	0.0	268	242	154	88	2.9	1.5	0.0
	E.S.	6.85	0.0	0.0	280	264	187	77	4.85	2.5	0.0
Oct. 19	Str.	7.6	10.4	12	190	253	154	99	0.65	0.2	0.0
	S.S.	7.1	0.0	0.0	246	231	143	88	2.9	2.5	0.0
	E.S.	6.9	0.0	0.0	406	407	253	154	B.S.	B.S.	B.S.
Nov. 3	Str.	7.8	11.2	28	186	231	154	77	1.98	0.0	0.0
	S.S.	7.05	0.0	0.0	260	231	209	22	2.6	2.5	0.0
	E.S.	6.85	0.0	0.0	310	319	209	110	1.3	0.4	0.0

Notes: Str. - Stream
S.S. - Submerged Sand
E.S. - Exposed Sand
T.H. - Total Hardness
A.E. - Analytical Error
B.S. - Broken Sample

Alkalinity

Bicarbonate alkalinity varied from 108 to 150 mgl in the stream (Table 6a). Somewhat greater fluctuation (104 to 224 mgl) was noted for submerged sand, and greater variation (150 to 252 mgl) with passage of time following exposure to air. Carbonate alkalinity (8 to 36 mgl) occurred only in stream water.

Total Hardness, Calcium, and Magnesium

Hardness fluctuation in stream water was from 142 to 188 mgl total hardness, 54 to 99 mgl calcium, and 46 to 110 mgl magnesium (Table 6a). Higher values and greater variation were noted in submerged sand where total hardness ranged from 148 to 152 mgl, calcium from 76 to 176 mgl, and magnesium from 55 to 132 mgl.

Exposed sand built up greater concentrations (144 to 274 mgl total hardness, 76 to 199 mgl calcium, and 66 to 100 mgl magnesium) as time passed following emergence from water. The calcium-magnesium ratio changed from 1.2:1.0 on July 30 to 2.6:1.0 on September 21.

Orthophosphate, Nitrite-Nitrogen, and Ammonia-Nitrogen

A limited number of samples were analyzed (Table 6a). Orthophosphate was present in all but one sample from exposed and submerged sands, but appeared only once in the stream. Nitrite-nitrogen never occurred but ammonia-nitrogen existed at all times in submerged sand, and most of the time in the stream and exposed sand.

Wild Rice River

Oxygen

Oxygen was conspicuous by its absence in both submerged and exposed sand regions (Table 6a).

Hydrogen Ion Concentration

Submerged and exposed sand exhibited lower pH readings than stream water (Table 6b), and exposed sand had values below those of sand under water.

Alkalinity

No carbonate alkalinity was noted in sand (Table 6b), and bicarbonate was greater in sand than in water and also more concentrated in exposed than in submerged sand. The stream exhibited carbonate alkalinity values between 2.5 and 32.0 mgl.

Total Hardness, Calcium, and Magnesium

Fluctuations in stream water were from 189 to 271 mgl total hardness, 99 to 167 mgl calcium, and 71 to 110 mgl magnesium (Table 6b). In submerged sand total hardness ranged from 208 to 400 mgl, calcium from 132 to 212 mgl, and magnesium from 24 to 191 mgl. Exposed sand exhibited greatest concentration and variation (231 to 693 mgl total hardness, 154 to 395 mgl calcium, and 56 to 287 mgl magnesium).

Calcium-magnesium ratios were as follows: the stream varied from 1.0:1.0 to 2.0:1.0; submerged sand, 1.0:1.4 at the beginning to 9.5:1.0 near the end of sampling; and exposed sand, 1.0:1.0 changing to 3.2:1.0.

Orthophosphate, Nitrite-Nitrogen, and Ammonia-Nitrogen

Orthophosphate generally showed an increase from water to submerged sand to exposed sand (Table 6b), but on two occasions, it was most concentrated in submerged sands. Nitrite-nitrogen was not found, but ammonia-nitrogen was highly concentrated in both submerged and exposed sands.

Biological Features

Qualitative Features

Organisms found in sand in the Mississippi and Wild Rice Rivers are listed below, with indication of their occurrence in either or both rivers.

Bacillariophyceae dominated the psammon in both rivers. Both Cyanophyta and Chlorphyta-Euglenophyta were of secondary importance in the Mississippi River, but Cyanophyta, especially the genus Oscillatoria, was at times the predominant alga in the exposed sand of the Wild Rice River. Testaceous rhizopods were the dominant animal forms in both rivers, with the Mississippi River exhibiting the greatest variety.

Quantitative Data

Only organisms that appeared to have been alive at the time of the collection were enumerated. Normally an individual, or cell, served as a counting unit, but with some colonial and filamentous forms the following designations were treated as units:

Coelosphaerium...............	1 colony
Merismopedia.................	100 cells
Gomphosphaeria...............	16 cells
Microcystis..................	1 grid (4761 μ^2)
Chroococcus..................	16 cells
Anabena......................	10 cells
Nostoc.......................	1 grid (4761 μ^2)
All other Nostocales.........	100 μ filament
Eudorina.....................	16 cells
Ulotrichales.................	100 μ filament
Microsporales................	100 μ filament
Chaetophorales...............	100 μ filament
Cladophorales................	100 μ filament
Oedogoniales.................	100 μ filament
Siphonales...................	100 μ filament
Mougeotia....................	100 μ filament
Spirogyra....................	100 μ filament
Pediastrum boryanum..........	15 cells
P. simplex...................	15 cells
P. duplex....................	15 cells
P. tetras....................	4 cells
Scenedesmus..................	4 cells
Sorastrum....................	1 colony
Coelastrum...................	1 colony

Diatoms were counted as individual cells, but forms that could not be separated at 100X were grouped as follows: (1) the Navicula group, including *Navicula*, some *Nitzschia*, *Neidium*, *Amphipleura*, *Achnanthes*, *Synedra*, *Frustulia*, *Stauroneis*, *Anomoeoneis*, and *Pinnularia*, and (2) the Fragilaria group, consisting of *Fragilaria* and *Opephora*.

Mississippi River

Transect 1

Algae. *Bacillariophyceae*. Diatoms were by far the most abundant life form in the potamopsammon (Table 7). Fluctuations of one million diatom cells per cubic centimeter of sand were not uncommon. These changes were initiated to a large degree by currents which removed and deposited diatoms along with finer grades of sand. As mentioned previously, sand grade distribution on June 13 indicated current erosion

List of Organisms

Bacteria

Schizomycophyta

Chromatium sp. WRR*

Sphaerotilus sp. WRR

Algae

Cyanophyta

Chroococcales

Chroococcus limneticus Lemmerman WRR

Chroococcus minutus (Kuetz.) Naegeli MR*

Chroococcus turgidus (Kuetz.) Naegeli WRR

Microcystis aeruginosa Kuetz.; emend. Elenkin MR, WRR

Microcystis flos-aquae (Wittr.) Kirchner MR

Microcystis incerta Lemmermann WRR

Merismopedia elegans A. Braun MR

Merismopedia glauca (Ehr.) Naegeli MR, WRR

Merismopedia Trolleri Bachmann MR

Coelosphaerium Naegelianum Unger MR

Gomphosphaeria aponina Kuetz. WRR

Gomphosphaeria lacustris Chodat MR

Gomphosphaeria lacustris var. *compacta* Lemmermann MR

Eucapsis alpina Clements and Schantz MR

Gloeothece rupestris (Lyngb.) Bornet
Syn. *Anacystis rupestris* (Lyngb.) Drouet and Daily WRR

*Note: MR = Mississippi River
WRR = Wild Rice River

List of Organisms - Continued

Nostocales

Spirulina laxissima G. S. West WRR

Spirulina major Kuetz. WRR

Arthrospira gomontiana Setchell MR

Oscillatoria acutissima Kufferath MR

Oscillatoria Agardhii Gomont WRR

Oscillatoria amoena (Kuetz.) Gomont MR

Oscillatoria amphibia C. A. Agardh WRR

Oscillatoria articulata Gardner WRR

Oscillatoria chalybea Mertens WRR

Oscillatoria curviceps C. A. Agardh WRR

Oscillatoria formosa Bory WRR

Oscillatoria limnetica Lemmermann MR

Oscillatoria limosa (Roth) C. A. Agardh MR

Oscillatoria negra Vaucher MR, WRR

Oscillatoria subbrevis Schmidle MR, WRR

Oscillatoria terebriformis C. A. Agardh MR, WRR

Lyngbya aestuarii (Mert.) Liebmann WRR

Lyngbya Birgei G. M. Smith MR

Microcoleus vaginatus (Vauch.) Gomont WRR

Aphanizomenon flos-aquae (L.) Ralfs MR

Anabena aequalis Borge WRR

Anabena affinis Lemmermann WRR

Anabena spiroides Klebahn MR

Anabena sp. MR

Nostoc paludosum Kuetz. MR, WRR

List of Organisms - Continued

Tolypothrix distorta Kuetz. MR, WRR

Hapalosiphon sp. WRR

Gloeotrichia natans (Hedwig) Rabenhorst WRR

Gloeotrichia pisum (C. A. Ag.) Thuret MR

Chrysophyta

Chrysophyceae

Chrysomonadales

Uroglenopsis americana (Calkins) Lemmermann MR

Xanthophyceae

Heterococcales

Ophiocytium sp. MR

Bacillariophyceae

Centrales

Melosira ambigua (Grun.) O. Mull. MR

Melosira granulata (Ehr.) Ralfs MR, WRR

Melosira varians C. A. Agardh MR, WRR

Cyclotella catenata Brun. WRR

Cyclotella comata (Ehr.) Kutz. MR

Cyclotella glomerata Bachmann WRR

Cyclotella Meneghiniana Kutz. MR, WRR

Cyclotella striata var. bipunctata Fricke. MR, WRR

Stephanodiscus niagarae MR

Pennales

Diatoma vulgare Bory var. vulgare Patrick MR, WRR

Tabellaria fenestrata (Lyngb.) Kutz. var. fenestrata Patrick MR, WRR

Tabellaria flocculosa (Roth) Kutz. var. flocculosa Patrick WRR

List of Organisms - Continued

Meridion circulare (Grev.) Ag. var. circulare Patrick MR

Opephora martyi Herib. var. martyi Patrick MR, WRR

Fragilaria brevistriata var. inflata (Pant.) Hust. MR

Fragilaria capucina var. mesolepta Rabh. WRR

Fragilaria construens (Ehr.) Grun. var. construens Patrick MR

Fragilaria Leptostauron var. dubia (Grun.) Hust. MR

Fragilaria pinnata var. intercedens (Grun) Hust. MR

Fragilaria vaucheriae (Kutz.) Peters. var. vaucheriae Patrick MR, WRR

Synedra acus Kutz. var. acus Patrick MR

Synedra capitata Ehr. var. capitata Patrick MR

Synedra delicatissma W. Sm. var. delicatissma Patrick MR

Synedra parasitica (W. Smith) Hust. var. parasitica Patrick WRR

Synedra parasitica var. subconstricta (Grun.) Hust. MR

Synedra ulna (Nitz.) Ehr. var. ulna Patrick WRR

Synedra ulna var. contracta Østr. MR

Synedra ulna var. longissima (W. Smith) Brun. WRR

Synedra ulna var. oxyrhynchus f. mediocontracta (Forti) Hust. MR

Asterionella formosa Hass. var. formosa Patrick MR

Eunotia monodon Ehr. var. monodon Patrick WRR

Eunotia praerupta Ehr. var. praerupta Patrick WRR

Eunotia sp. MR

Cocconeis pediculus Ehr. var. pediculus Patrick MR, WRR

Cocconeis placentula Ehr. var. placentula Patrick MR

Cocconeis placentula var. euglypta (Ehr.) Cl. MR

Cocconeis placentula var. lineata (Ehr.) V. H. WRR

Achnanthes clevei Grun. var. clevei Patrick MR

List of Organisms - Continued

Achnanthes clevei var. rostrata Hust. MR

Achnanthes exigua var. constricta (Grun.) Hust. MR

Achnanthes lanceolata (Breb.) Grun. var. lanceolata Patrick MR, WRR

Achnanthes lanceolata var. dubia Grun. MR, WRR

Achnanthes lanceolata var. haynaldii (Istu. - Schaarsch.) Cl. MR

Achnanthes linearis (W. Smith) Grun. var. linearis Patrick WRR

Rhiocosphenia curvata (Kutx.) Grun. var. curvata Patrick MR, WRR

Amphipleura pellucida Kutz. var. pellucida Patrick MR, WRR

Frustulia rhomboides (Ehr.) DeT. var. rhomboides Patrick WRR

Frustulia vulgaris (Thwaites) DeT. var. vulgaris Patrick WRR

Gyrosigma acuminatum (Kutz.) Rabh. var. acuminatum Patrick WRR

Gyrosigma attenuatum (Kutz.) Rabh. var. attenuatum Patrick MR

Gyrosigma obtusatum (Sulliv. and Wormley) Boyer var. obtusatum WRR

Stauroneis kriegeri Patrick var. kriegeri Patrick WRR

Stauroneis phoenicenteron f. gracilis (Ehr.) Hust. WRR

Stauroneis salina W. Sm. MR

Stauroneis smithii Grun. var. smithii Patrick MR

Anomoeoneis sphaerophora (Ehr.) Pfitz. var. sphaerophora Patrick WRR

Neidium affine var. humerus Reim. var. nov. WRR

Neidium dubium (Ehr.) Cl. var. dubium Patrick MR

Neidium kozlowii var. parvum Mereschk WRR

Navicula anglica var. subsalsa (Grun.) Cl. MR, WRR

Navicula capitata Ehr. var. capitata Patrick MR, WRR

Navicula cryptocephala var. veneta (Kutz.) Rabh. MR

Navicula cuspidata (Kutz.) Kutz. var. cuspidata Patrick MR, WRR

Navicula declivis Hust. MR

List of Organisms - Continued

Navicula gastrum (Ehr.) Kutz. var. gastrum Patrick MR, WRR

Navicula halophila (Grun.) Cl. var. halophila Patrick WRR

Navicula hambergii Hust. var. hambergii Patrick WRR

Navicula laterostrata Hust. var. laterostrata Patrick MR

Navicula menisculus var. upsaliensis (Grun.) Grun. MR, WRR

Navicula odiosa Wallace var. odiosa Patrick WRR

Navicula protracta Grun. var. protracta Patrick WRR

Navicula pupula Kutz. var. elliptica Hust. MR

Navicula pupula var. rectangularis (Greg.) Grun. MR, WRR

Navicula radiosa var. tenella (Breb. ex Kutz.) Grun. MR

Navicula reinhardtii (Grun.) Grun. var. reinhardtii Patrick MR

Navicula salinarum Grun. var. salinarum Patrick MR

Navicula salinarum var. intermedia (Grun.) Cl. MR, WRR

Navicula seminulum var. hustedtii Patrick WRR

Navicula texana Patrick var. texana Patrick WRR

Navicula tripunctata (O. F. Mull.) Bory var. tripunctata Patrick WRR

Navicula tuscula Ehr. var. tuscula Patrick MR

Navicula vulpina Kutz. var. vulpina Patrick MR

Navicula spp. MR, WRR

Caloneis bacillum (Grun.) Cl. var. bacillum Patrick WRR

Caloneis lewisii Patrick var. lewisii Patrick WRR

Caloneis limosa (Kutz.) Patrick comb. nov., var. limosa Patrick WRR

Pinnularia spp. MR, WRR

Amphiprora alata Kutz. MR

Amphiprora ornata Bailey MR, WRR

Amphora coffeaeformis Agardh MR

List of Organisms - Continued

Amphora ovalis var. libyca (Ehr.) Cl. MR

Amphora ovalis var. pediculus Kutz. MR, WRR

Cymbella affinis Kutz. MR

Cymbella cistula (Hemprich) Grun. MR

Cymbella ehrenbergii Kutz. WRR

Cymbella gracilis (Rabh.) Cl. WRR

Cymbella hebridica (Greg.) Grun. MR

Cymbella obtusiuscula (Kutz.) Grun. WRR

Cymbella prostata (Berkeley) Cl. MR, WRR

Cymbella sinuata Greg. MR, WRR

Cymbella tumida (Breb.) Van Heurck WRR

Cymbella ventricosa Kutz. MR, WRR

Gomphonema acuminatum var. brebissonii (Kutz.) Cl. MR, WRR

Gomphonema acuminatum var. coronata (Ehr.) W. Sm. MR

Gomphonema acuminatum var. trigonocephala (Ehr.) Grun. MR, WRR

Gomphonema angustatus var. producta Grun. MR, WRR

Gomphonema constrictum Ehr. MR

Gomphonema gracile Ehr. WRR

Gomphonema intricatum Kutz. MR

Gomphonema intricatum var. pumila Grun. MR, WRR

Gomphonema olivaceum (Lyng.) Kutz. WRR

Gomphonema parvulum var. micropus (Kutz.) Cl. MR

Gomphonema sphaerophorum Ehr. MR

Epithemia argus var. longicornis Grun. WRR

Epithemia sorex Kutz. MR, WRR

Epithemia turgida (Ehr.) Kutz. MR, WRR

List of Organisms - Continued

Rhopalodia gibba (Ehr.) O. Mull. MR, WRR

Rhopalodia gibba var. ventricosa (Ehr.) Grun. MR

Rhopalodia giberula (Ehr.) O. Mull. WRR

Cylindrotheca gracilis (Breb.) Grun. WRR

Hantzschia amphioxys (Ehr.) Grun. WRR

Hantzschia amphioxys var. maior Grun. WRR

Hantzschia sp. MR

Nitzschia acicularis W. Sm. MR, WRR

Nitzschia acuta Hantzsch WRR

Nitzschia amphibia Grun. MR

Nitzschia dissipata (Kutz.) Grun. MR, WRR

Nitzschia filiformis (W. Sm.) Hust. MR, WRR

Nitzschia fonticola Grun. MR

Nitzschia palea (Kutz.) W. Sm. WRR

Nitzschia sigmoidea (Ehr.) W. Sm. MR, WRR

Nitzschia sp. WRR

Cymatopleura solea (Breb.) W. Sm. MR, WRR

Cymatopleura solea var. regula (Ehr.) Grun. MR

Surirella angustata Kutz. WRR

Surirella elegans Ehr. MR

Surirella linearis var. helvetica (Brun.) Meister WRR

Surirella ovata Kutz. MR, WRR

Surirella ovalis Breb. MR

Surirella robusta var. splendida (Ehr.) Van Heurck WRR

Surirella spiralis Kutz. MR, WRR

List of Organisms - Continued

Chlorophyta

Volvocales

Eudorina elegans Ehr. MR, WRR

Tetrasporales

Sphaerocystis schroeteri Chodat MR

Ulotrichales

Stichococcus bacillaris Naegeli WRR

Ulothrix zonata (Weber and Mohr) Kuetz. MR

Microsporales

Microspora stagnorum (Kuetz.) Lagerheim MR

Chaetophorales

Stigeoclonium pachydermum Prescott WRR

Stigeoclonium sp. MR

Cladophorales

Cladophora sp. MR, WRR

Oedogoniales

Bulbochaete sp. MR

Oedogonium sp. MR

Chlorococcales

Pediastrum boryanum (Turp.) Meneghini MR, WRR

Pediastrum duplex Meyen MR, WRR

Pediastrum duplex var. clathratum (A. Braun) Lagerheim MR

Pediastrum glanduliferum Bennett MR

Pediastrum simplex (Meyen) Lemmermann MR

Pediastrum tetras (Ehr.) Ralfs MR, WRR

Sorastrum spinulosum Naegeli MR

List of Organisms - Continued

Coelastrum microporum Naegeli MR

Dictyosphaerium pulchellum Wood MR

Oocystis borgei Snow MR

Oocystis sp. WRR

Dimorphococcus lunatus A. Braun MR

Ankistrodesmus falcatus (Corda) Ralfs MR

Tetraedron constrictum G. M. Sm. MR

Tetraedron hastatum (Reinsch) Hansgirg MR

Tetraedron trigonum var. gracile (Reinsch) DeToni MR

Scenedesmus arcuatus var. platydisca G. M. Sm. MR

Scenedesmus dimorphus (Turp.) Breb. MR, WRR

Scenedesmus opoliensis var. contacta Prescott WRR

Scenedesmus quadricauda (Turp.) Breb. MR, WRR

Actinastrum gracilimum G. M. Sm. MR

Crucigenia rectangularis (A. Braun) Gay MR

Siphonales

Vaucheria sp. WRR

Zygnematales

Mougeotia sp. MR

Spirogyra sp. MR, WRR

Closterium moniliferum (Bory.) Ehr. MR, WRR

Closterium sp. MR, WRR

Cosmarium spp. MR, WRR

Euastrum spp. MR

Netrium sp. MR

Staurastrum sp. MR

List of Organisms - Continued

Euglenophyta

Euglenales

Euglena acus Ehr. WRR

Euglena acus var. *angularis* Johnson WRR

Euglena chlamydophora Mainx WRR

Euglena deses Ehr. WRR

Euglena proxima Dangeard MR

Euglena terricola Dangeard WRR

Phacus acuminatus Stokes WRR

Phacus spirogyra var. *maxima* Prescott WRR

Phacus triqueter (Ehr.) Dujardin WRR

Phacus sp. MR

Trachelomonas acanthostoma (Stokes) Deflandre MR

Trachelomonas varians (Lemm.) Deflandre MR

Trachelomonas volvocina Ehr. MR

Trachelomonas sp. WRR

Paranema sp. WRR

Pyrrhophyta

Peridiniales

Peridinium sp. MR

Ceratium carolinianum (Bailey) Jorgenson MR

Ceratium hirundinella (O. F. Muell.) Dujardin MR

List of Organisms - Continued

Animals

Rhizopoda

Testacealobosa

Microchlamys patella Claparede and Lachmann MR

Arcella dentata Ehr. MR

Arcella discoides Ehr. MR

Arcella vulgaris Ehr. MR, WRR

Pyxidicula cymbalum Penard MR

Pyxidicula operculata Ehr. MR

Centropyxis aculeata (Ehr.) Stein MR, WRR

Centropyxis ecornis (Ehr.) Leidy MR

Difflugia acuminata Ehr. MR, WRR

Difflugia constricta (Ehr.) Leidy MR, WRR

Difflugia corona Wallich MR

Difflugia globulosa Dujardin MR, WRR

Difflugia lebes Penard MR

Difflugia lobostoma Leidy MR

Difflugia oblonga Ehr. MR, WRR

Difflugia spiralis Ehr. MR, WRR

Difflugia urceolata Carter WRR

Quadrulella symmetrica Wallich MR, WRR

Nebela collaris Ehr. MR

Wailesella eboracensis Wailes MR

Testaceafilosa

Cyphoderia ampulla Ehr. MR, WRR

List of Organisms - Continued

Cyphoderia ampulla var. papillata Wailes MR, WRR

Pareuglypha reticulata Penard MR

Euglypha alveolata Dujardin MR

Euglypha ciliata Ehr. MR, WRR

Euglypha laevis Ehr. MR, WRR

Trinema enchelys Ehr. MR

Trinema lineare Penard MR

Ciliophora

Holotrichida

Lionotus sp. MR, WRR

Loxodes magnus Stokes MR

Loxodes sp. MR

Paramecium sp. WRR

Pseudoprorodon sp. MR

Spirotrichida

Blepharisma lateritum Ehr. MR

Blepharisma sp. MR

Codonella cratera (Leidy) MR, WRR

Eschaneustyla brachytona Stokes MR

Eupoltes sp. MR, WRR

Urosoma sp. WRR

Peritrichida

Cothurnia sp. MR

Vorticella sp. MR

List of Organisms - Continued

Tentaculiferida

Podophrya sp. WRR

Sphaerophrya sp. WRR

Nematoda

Nematoda spp. MR, WRR

Gastrotricha

Chaetonotus sp. MR, WRR

Rotifera

Ploima

Keratella cochlearis Ahlstrom MR

Trichocerca sp. MR, WRR

Colurella adriatica Carlin MR, WRR

Trichotria sp. MR

Lepadella patella (Muller) MR, WRR

Lepadella sp. MR, WRR

Cephalodella exigua Harring and Myer MR

Cephalodella spp. MR, WRR

Lecane ohioensis (Herrick) MR

Lecane flexilis (Gosse) WRR

Lecane spp. MR, WRR

Monostyla closterocerca Pennak MR, WRR

Monostyla hamata (Stokes) MR

Monostyla psammophilia Wiszniewski MR, WRR

Monostyla sp. MR, WRR

Lindia sp. WRR

List of Organisms - Continued

Bdelloida

Rotaria sp. MR, WRR

Philodina sp. MR, WRR

Tardigrada

Hypsibius sp. MR, WRR

Macrobiotus sp. WRR

Annelida

Oligochaeta

Oligochaeta spp. WRR

Aeolosoma sp. MR

Arthropoda

Crustacea

Cladocera

Bosmina sp. MR

Ostracoda

Ostracoda spp. MR, WRR

Copepoda

Cyclopoida spp. MR

Nauplius larvae MR

Insecta

Plecoptera nymphs MR

Ephemeroptera nymphs MR

Trichoptera larvae MR

Coleoptera

Dytiscidae adult MR

List of Organisms - Continued

Diptera

Ceratopogonidae larvae MR

Chironomidae larvae MR, WRR

Acari

Larval mites MR

TABLE 7

VERTICAL AND HORIZONTAL DISTRIBUTION OF PSAMMON ORGANISMS
FOR THE MISSISSIPPI RIVER, NUMBERS ARE
PER CUBIC CENTIMETER OF SAND

A. Mississippi River - June 13, 1968

Organism	Depth (cm)	Stations 1	2	3	4	5	6
Diatoms	1	1,072,806	183,740	254,160	1,297,363	1,732,787	287,795
	2	683,061	32,549	130,135	419,316	710,909	5,668
	3	375,510	1,640	38,452	228,471	593,949	1,676
	4	282,918	1,084	544	3,612	150,534	304
	5	N.S.	300	120	1,320	91,233	N.S.
	6	N.S.	256	144	292	6,980	N.S.
Blue-Green Algae	1	13,800	708	1,262	420	902	302
	2	17,922	1,745	3,332	332	666	36
	3	6,161	4,924	524	4	278	0
	4	2,337	804	40	0	16	0
	5	N.S.	48	12	0	8	N.S.
	6	N.S.	16	52	0	0	N.S.
Green Algae	1	1,960	84	100	3,816	3,064	128
	2	172	88	56	604	900	20
	3	456	360	24	164	700	4
	4	516	96	8	92	140	0
	5	N.S.	44	20	16	48	N.S.
	6	N.S.	0	0	0	68	N.S.

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
Rhizopoda	1	216	20	24	128	436	328
	2	68	60	68	28	284	104
	3	96	168	88	12	144	136
	4	56	292	28	88	84	48
	5	N.S.	92	20	80	180	N.S.
	6	N.S.	84	20	40	84	N.S.
Rotifera	1	96	16	32	60	160	52
	2	8	0	8	0	8	8
	3	4	4	0	0	0	8
	4	0	4	0	0	4	0
	5	N.S.	0	0	0	0	N.S.
	6	N.S.	0	0	0	0	N.S.
Nematoda	1	24	40	36	52	136	52
	2	20	72	0	4	56	4
	3	4	12	12	0	28	12
	4	8	8	8	0	4	0
	5	N.S.	4	0	4	4	N.S.
	6	N.S.	8	4	0	0	N.S.
Tardigrada	1	64	24	188	52	72	0
	2	4	20	12	56	44	8
	3	20	0	16	4	4	0
	4	4	0	16	0	4	0
	5	N.S.	0	20	0	0	N.S.
	6	N.S.	0	0	0	0	N.S.

TABLE 7 - Continued

Organism	Depth (cm)	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Others	1	16	4	56	60	88	40
	2	0	4	0	8	0	0
	3	0	0	0	4	8	0
	4	0	0	0	0	0	0
	5	N.S.	0	0	4	0	N.S.
	6	N.S.	0	0	0	0	N.S.
B. Mississippi River - July 2, 1968							
Diatoms	1	210,395	199,697	118,620	91,653	444,951	1,687,917
	2	63,346	40,590	66,129	51,711	33,392	670,647
	3	5,412	2,404	3,532	2,072	18,240	359,069
	4	1,348	1,428	2,744	936	5,160	14,164
	5	468	364	952	292	1,788	8,532
	6	268	192	N.S.	144	108	3,104
Blue-Green Algae	1	269	1,401	469	291	358	8,760
	2	536	1,427	548	120	124	2,022
	3	365	456	620	12	12	16
	4	16	64	2,920	40	0	0
	5	20	62	926	16	0	72
	6	20	0	N.S.	32	0	0
Green Algae	1	232	720	256	336	344	2,092
	2	180	32	128	56	848	384
	3	228	62	44	32	384	156

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
	4	12	12	64	20	188	256
	5	0	18	12	0	16	40
	6	12	10	N.S.	8	0	24
Rhizopoda	1	248	268	416	112	344	840
	2	120	8	208	88	136	336
	3	124	104	108	24	216	218
	4	16	72	76	40	96	204
	5	12	14	64	8	72	168
	6	12	8	N.S.	16	80	180
Rotifera	1	84	168	52	92	4	8
	2	24	0	16	16	0	4
	3	8	16	8	8	0	0
	4	0	0	4	0	0	0
	5	0	2	0	0	0	0
	6	0	4	N.S.	0	0	0
Nematoda	1	12	56	52	28	0	60
	2	4	0	20	0	8	60
	3	8	4	0	4	0	4
	4	0	4	0	4	0	0
	5	0	8	0	0	0	0
	6	4	6	N.S.	4	4	0
Tardigrada	1	104	68	12	112	32	0
	2	24	4	0	24	0	0
	3	8	0	0	12	0	0

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
	4	4	8	0	20	4	0
	5	0	0	0	8	0	0
	6	0	0	N.S.	4	0	0
Others	1	40	8	4	20	0	28
	2	16	0	36	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
C. Mississippi River - July 16, 1968							
Diatoms	1	1,050,339	6,604	2,324	30,752	78,268	N.C.
	2	187,748	1,672	496	7,100	24,430	
	3	40,727	1,892	412	2,488	596	
	4	1,308	1,412	300	1,156	276	
	5	1,248	304	260	220	132	
	6	1,306	N.S.	N.S.	128	N.S.	
Blue-Green Algae	1	796	31	36	169	196	
	2	222	28	243	49	33	
	3	20	0	224	36	16	
	4	8	0	276	40	0	
	5	0	0	8	40	8	
	6	0	N.S.	N.S.	22	N.S.	

TABLE 7 - Continued

Organism	Depth	Stations					
	(cm)	1	2	3	4	5	6
Green Algae	1	920	1,596	52	232	140	N.C.
	2	164	16	12	208	20	
	3	72	0	16	40	0	
	4	88	12	4	64	0	
	5	28	412	0	16	0	
	6	16	N.S.	N.S.	12	N.S.	
Rhizopoda	1	300	4	100	60	112	
	2	102	4	68	20	88	
	3	36	0	52	12	24	
	4	56	0	40	16	16	
	5	72	8	0	4	8	
	6	32	N.S.	N.S.	8	N.S.	
Rotifera	1	32	12	32	72	0	
	2	0	8	8	48	0	
	3	0	0	4	16	0	
	4	0	0	8	20	0	
	5	0	0	0	8	0	
	6	0	N.S.	N.S.	0	N.S.	
Nematoda	1	4	0	4	8	8	
	2	4	4	4	16	0	
	3	0	0	0	4	0	
	4	0	0	0	0	0	
	5	0	0	4	0	0	
	6	0	N.S.	N.S.	0	N.S.	
Tardigrada	1	12	32	16	16	24	

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
	2	16	4	0	4	24	N.C.
	3	4	16	12	8	0	
	4	0	0	0	16	0	
	5	0	0	0	20	0	
	6	0	N.S.	N.S.	8	N.S.	
Others	1	0	0	8	4	0	
	2	0	0	4	4	0	
	3	0	0	0	0	0	
	4	0	0	0	0	0	
	5	0	0	0	0	0	
	6	0	N.S.	N.S.	0	N.S.	
D. Mississippi River - July 30, 1968							
Diatoms	1	Broken	Broken	7,047	2,388	34,030	N.C.
	2	2,181,824	129,740	58,999	Broken	700	
	3	193,559	260,201	81,485	1,624	276	
	4	2,736	118,157	2,104	1,784	324	
	5	4,280	2,148	620	328	28	
	6	264	584	744	N.S.	20	
Blue-Green Algae	1	Broken	Broken	28	4	2,769	
	2	704	237	508	Broken	72	
	3	0	80	673	104	24	
	4	0	146	454	96	234	
	5	8	132	32	0	128	
	6	0	12	8	N.S.	0	

TABLE 7 - Continued

Organism	Depth (cm)	Stations					
		1	2	3	4	5	6
Green Algae	1	Broken	Broken	124	180	3,964	N.C.
	2	976	156	228	Broken	8	
	3	56	116	184	48	0	
	4	24	120	76	600	0	
	5	8	132	24	24	0	
	6	12	8	24	N.S.	0	
Rhizopoda	1	Broken	Broken	152	84	550	
	2	504	64	480	Broken	8	
	3	368	68	472	80	28	
	4	200	84	1,532	216	24	
	5	112	24	1,852	64	16	
	6	60	12	1,224	N.S.	32	
Rotifera	1	Broken	Broken	160	4	0	
	2	0	8	80	Broken	0	
	3	0	12	72	0	0	
	4	0	16	52	0	0	
	5	8	0	24	0	0	
	6	0	0	24	N.S.	0	
Nematoda	1	Broken	Broken	12	4	10	
	2	0	0	8	Broken	0	
	3	0	0	0	4	0	
	4	0	0	0	8	0	
	5	0	0	0	8	0	
	6	4	0	0	N.S.	0	

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
Tardigrada	1	Broken	Broken	0	0	0	N.C.
	2	24	4	24	Broken	0	
	3	8	4	0	0	0	
	4	0	0	0	0	0	
	5	0	0	0	0	0	
	6	0	0	0	N.S.	0	
Others	1	Broken	Broken	24	0	0	
	2	32	0	44	Broken	0	
	3	0	4	24	0	8	
	4	16	0	12	0	16	
	5	0	0	4	0	0	
	6	0	0	4	N.S.	0	
E. Mississippi River, August 14, 1968							
Diatoms	1	1,316,322	472,215	474,090	44,743	236,678	
	2	55,292	102,601	397,687	11,487	7,392	
	3	2,460	15,093	107,130	1,968	4,580	
	4	1,756	7,641	40,431	448	208	
	5	N.S.	112	26,648	200	100	
	6	N.S.	66	N.S.	48	8	
Blue-Green Algae	1	464	322	460	9	720	
	2	16	60	828	88	36	
	3	16	0	234	370	60	
	4	0	0	72	16	0	

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
	5	N.S.	0	4	0	0	N.C.
	6	N.S.	0	N.S.	0	0	
Green Algae	1	3,296	1,300	1,690	336	4,476	
	2	68	108	1,448	444	464	
	3	40	48	748	168	332	
	4	36	4	222	104	16	
	5	N.S.	8	100	56	8	
	6	N.S.	8	N.S.	24	8	
Rhizopoda	1	1,556	412	1,636	424	1,252	
	2	380	168	1,380	520	812	
	3	112	52	632	602	2,256	
	4	80	32	268	416	252	
	5	N.S.	52	208	208	88	
	6	N.S.	2	N.S.	48	24	
Rotifera	1	164	252	452	96	40	
	2	8	48	140	48	8	
	3	4	8	60	20	4	
	4	4	0	20	8	0	
	5	N.S.	0	28	0	0	
	6	N.S.	0	N.S.	0	0	
Nematoda	1	100	4	32	0	8	
	2	8	0	12	4	4	
	3	0	4	4	4	8	
	4	0	0	4	0	4	
	5	N.S.	0	0	8	0	

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
	6	N.S.	0	N.S.	0	0	N.C.
Tardigrada	1	0	20	40	0	4	
	2	8	12	24	0	0	
	3	8	4	0	8	16	
	4	0	0	12	0	0	
	5	N.S.	0	4	0	0	
	6	N.S.	0	N.S.	0	0	
Others	1	52	76	108	16	12	
	2	0	12	56	32	0	
	3	0	0	0	8	0	
	4	0	0	8	0	0	
	5	N.S.	0	0	0	4	
	6	N.S.	0	N.S.	0	0	
F. Mississippi River - August 27, 1968							
Diatoms	1	500,689	137,086	102,814	595,300	321,580	
	2	36,541	49,551	17,720	37,827	44,049	
	3	18,895	58,094	10,921	1,344	828	
	4	1,132	29,509	696	212	84	
	5	784	1,200	152	168	216	
	6	160	236	N.S.	N.S.	28	
Blue-Green Algae	1	1,592	456	120	1,142	15,758	
	2	68	0	48	1,440	640	
	3	24	4	116	168	100	

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
	4	0	0	12	0	44	N.C.
	5	0	28	20	0	8	
	6	0	0	N.S.	N.S.	16	
Green Algae	1	9,346	356	488	1,548	2,180	
	2	76	108	76	168	308	
	3	36	56	64	24	100	
	4	4	44	56	16	28	
	5	8	24	40	0	0	
	6	12	12	N.S.	N.S.	4	
Rhizopoda	1	768	532	442	1,128	1,304	
	2	68	132	136	96	380	
	3	68	144	180	104	148	
	4	64	44	180	392	16	
	5	40	68	60	176	20	
	6	0	0	N.S.	N.S.	36	
Rotifera	1	60	104	40	4	68	
	2	8	24	8	0	4	
	3	0	8	4	0	0	
	4	0	0	0	0	0	
	5	0	0	0	0	0	
	6	0	0	N.S.	N.S.	0	
Nematoda	1	144	32	16	88	44	
	2	12	8	4	4	24	
	3	8	4	4	4	0	

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
	4	0	8	4	0	0	N.C.
	5	0	0	0	16	0	
	6	0	0	N.S.	N.S.	0	
Tardigrada	1	0	44	8	4	0	
	2	0	0	0	0	4	
	3	0	0	4	4	0	
	4	0	0	4	4	0	
	5	0	0	0	0	0	
	6	0	4	N.S.	N.S.	0	
Others	1	176	136	92	0	32	
	2	20	16	0	0	56	
	3	12	4	8	4	8	
	4	0	4	20	0	20	
	5	4	56	0	0	0	
	6	0	0	N.S.	N.S.	0	
G. Mississippi River - September 21, 1968							
Diatoms	1	221,224	368,286	53,945	68,016	113,802	
	2	26,522	14,264	41,382	54,039	125,879	
	3	2,172	11,060	1,368	31,483	11,862	
	4	11,138	5,580	1,664	5,736	2,892	
	5	840	2,380	860	3,544	2,320	
	6	504	132	180	N.S.	144	
Blue-Green Algae	1	600	3,436	0	608	180	

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
	2	180	840	0	464	48	N.C.
	3	12	1,040	0	20	20	
	4	24	128	0	400	120	
	5	0	8	0	272	8	
	6	8	2	0	N.S.	10	
Green Algae	1	876	436	312	292	4,372	
	2	348	72	0	164	2,648	
	3	60	124	20	56	804	
	4	28	56	8	196	1,556	
	5	124	28	0	96	1,560	
	6	164	4	0	N.S.	8	
Rhizopoda	1	2,268	664	208	744	1,660	
	2	216	180	64	904	4,408	
	3	132	212	140	436	1,508	
	4	56	108	92	540	1,648	
	5	40	84	138	284	1,404	
	6	32	16	90	N.S.	258	
Rotifera	1	8	28	0	12	4	
	2	0	8	0	16	16	
	3	0	8	0	0	0	
	4	0	0	0	0	0	
	5	0	0	0	0	0	
	6	0	0	0	N.S.	0	
Nematoda	1	36	0	0	12	8	
	2	20	4	0	24	8	

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
	3	24	0	0	0	24	N.C.
	4	4	4	0	4	24	
	5	8	0	0	0	0	
	6	0	0	0	N.S.	0	
Tardigrada	1	0	0	0	4	0	
	2	0	0	0	12	0	
	3	0	0	0	0	0	
	4	0	0	0	0	4	
	5	0	0	0	0	0	
	6	0	2	0	N.S.	0	
Others	1	80	24	0	24	16	
	2	0	0	0	4	16	
	3	0	0	0	0	0	
	4	0	0	0	4	0	
	5	0	0	0	12	0	
	6	0	0	0	N.S.	0	
H. Mississippi River - October 6, 1968							
Diatoms	1	1,246,375	652,540	330,447	154,433	237,903	
	2	53,985	274,868	115,875	36,815	71,269	
	3	38,732	261,938	60,633	4,664	37,432	
	4	1,984	48,561	8,532	5,984	30,053	
	5	672	3,192	3,770	N.S.	1,920	
	6	648	2,616	3,516	N.S.	240	

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
Blue-Green Algae	1	5,308	186	12,832	16,124	1,120	N.C.
	2	20	134	4,888	1,680	320	
	3	32	340	2,060	2,112	116	
	4	0	96	1,356	412	160	
	5	8	0	616	N.S.	30	
	6	12	0	228	N.S.	0	
Green Algae	1	19,757	268	556	432	512	
	2	384	86	344	96	448	
	3	258	166	64	232	140	
	4	560	1,216	132	224	36	
	5	128	56	34	N.S.	0	
	6	152	0	28	N.S.	0	
Rhizopoda	1	2,212	388	536	892	256	
	2	120	160	224	432	132	
	3	80	130	92	860	220	
	4	52	96	108	1,096	100	
	5	28	272	72	N.S.	112	
	6	24	176	64	N.S.	48	
Rotifera	1	12	10	28	8	36	
	2	0	10	20	16	8	
	3	0	0	8	4	4	
	4	0	0	12	12	0	
	5	0	0	0	N.S.	0	
	6	0	0	0	N.S.	0	

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
Nematoda	1	100	0	28	60	20	N.C.
	2	24	0	4	4	4	
	3	4	0	4	32	0	
	4	4	0	8	20	0	
	5	4	0	0	N.S.	0	
	6	0	0	0	N.S.	0	
Tardigrada	1	8	0	4	8	0	
	2	0	0	0	0	0	
	3	0	0	0	8	0	
	4	0	0	0	0	0	
	5	0	0	0	N.S.	0	
	6	0	0	8	N.S.	0	
Others	1	60	20	36	96	417	
	2	8	0	0	0	4	
	3	4	10	0	0	0	
	4	0	0	0	12	0	
	5	0	0	0	N.S.	0	
	6	0	0	0	N.S.	0	
I. Mississippi River - October 19, 1968							
Diatoms	1	1,397,509	796,957	141,231	557,397	N.C.	N.C.
	2	661,247	176,769	50,683	38,558		
	3	121,225	62,976	73,257	2,624		
	4	53,728	60,444	1,900	1,172		

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
	5	19,064	2,992	2,272	710	N.C.	N.C.
	6	8,100	956	2,112	72		
Blue-Green Algae	1	1,652	31,685	1,856	54		
	2	240	164	60	0		
	3	64	56	16	24		
	4	48	60	28	0		
	5	18	0	72	0		
	6	0	16	0	0		
Green Algae	1	11,705	1,008	416	548		
	2	8,141	252	280	76		
	3	476	116	68	40		
	4	180	76	48	0		
	5	612	12	32	52		
	6	424	20	12	0		
Rhizopoda	1	1,326	760	532	148		
	2	624	252	372	260		
	3	276	80	264	360		
	4	204	52	244	264		
	5	176	48	228	80		
	6	60	76	176	48		
Rotifera	1	24	96	12	0		
	2	0	0	4	0		
	3	0	8	4	0		
	4	0	0	0	0		

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
	5	0	0	12	0	N.C.	N.C.
	6	0	0	0	0		
Nematoda	1	136	32	12	8		
	2	32	4	4	0		
	3	28	0	0	8		
	4	0	8	0	0		
	5	0	0	8	0		
	6	0	0	0	0		
Tardigrada	1	0	8	0	0		
	2	0	0	0	0		
	3	0	0	0	0		
	4	0	0	0	0		
	5	0	0	0	0		
	6	0	0	0	0		
Others	1	16	64	48	0		
	2	0	0	4	0		
	3	0	0	0	0		
	4	0	0	0	0		
	5	0	0	0	0		
	6	0	0	0	0		
J. Mississippi River - November 3, 1968							
Diatoms	1	2,429,910	63,482	699,273	489,377		

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
	2	340,567	73,069	225,889	170,471	N.C.	N.C.
	3	112,336	520,295	83,960	17,890		
	4	99,331	1,078,934	98,467	4,156		
	5	9,436	187,378	12,396	1,144		
	6	9,276	11,780	N.S.	480		
Blue-Green Algae	1	13,430	276	816	287		
	2	448	528	2,952	0		
	3	64	14,317	1,172	60		
	4	12	62,038	12	16		
	5	40	48	8	0		
	6	56	0	N.S.	10		
Green Algae	1	18,111	216	552	392		
	2	809	132	432	158		
	3	112	10,386	124	10		
	4	16	12,478	104	0		
	5	12	968	92	0		
	6	68	48	N.S.	0		
Rhizopoda	1	994	70	632	888		
	2	448	116	672	366		
	3	416	720	308	140		
	4	156	2,372	96	250		
	5	376	352	80	120		
	6	112	76	N.S.	180		
Rotifera	1	30	40	88	20		

TABLE 7 - Continued

Organism	Depth (cm)	Stations 1	2	3	4	5	6
	2	8	16	40	0	N.C.	N.C.
	3	0	40	4	0		
	4	0	40	4	10		
	5	0	16	0	0		
	6	0	0	N.S.	0		
Nematoda	1	120	70	40	76		
	2	16	64	32	0		
	3	0	96	88	0		
	4	0	216	16	0		
	5	0	32	0	0		
	6	0	8	N.S.	0		
Tardigrada	1	0	4	8	0		
	2	8	0	32	0		
	3	0	0	0	0		
	4	0	0	0	0		
	5	0	0	0	0		
	6	0	0	N.S.	0		
Others	1	74	56	80	0		
	2	48	16	0	0		
	3	0	8	0	0		
	4	4	40	4	0		
	5	0	0	0	0		
	6	0	0	N.S.	0		

Note: N.S. means No Sample and N.C. means No Core

TABLE 8

VERTICAL AND HORIZONTAL DISTRIBUTION OF PSAMMON ORGANISMS FOR THE WILD RICE RIVER, NUMBERS ARE PER CUBIC CENTIMETER OF SAND

A. Wild Rice River - June 13, 1968

Organism	Depth (cm)	Distance Relative to Waterline, cm					
		+210	+140	+70	0	-70	-140
Diatoms	1	816	4,196	202,048	28	2,816	234,174
	2	8	164	690	62	200	30,430
	3	4	20	454	52	40	45,932
	4	0	4	344	24	32	5,788
	5	0	0	112	36	32	2,116
	6	0	0	80	28	24	480
Blue-Green Algae	1	6,348	20,176	3,794	36	172	239
	2	4	50	64	84	8	60
	3	0	4	0	4	0	88
	4	0	0	0	0	24	36
	5	0	0	0	0	40	57
	6	0	0	0	0	6	20
Green Algae	1	48	1,348	90	0	0	2,048
	2	0	40	18	8	0	404
	3	0	20	0	0	0	4,162
	4	0	0	0	0	0	416
	5	0	0	0	0	0	400
	6	0	0	0	0	0	36

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm					
		+210	+140	+70	0	-70	-140
Rhizopoda	1	104	8	58	36	8	272
	2	80	0	70	16	40	590
	3	24	0	20	20	88	180
	4	16	24	80	16	144	20
	5	12	36	24	20	64	16
	6	24	16	24	8	80	8
Nematoda	1	194	236	150	8	0	24
	2	16	24	10	8	0	8
	3	8	0	0	0	0	0
	4	16	8	0	0	0	0
	5	4	4	0	4	8	4
	6	4	16	0	0	0	0
Others	1	60	72	40	16	32	176
	2	0	8	0	16	24	68
	3	20	0	0	16	16	70
	4	0	8	0	12	24	52
	5	8	4	0	20	16	16
	6	4	4	0	8	16	4
B. Wild Rice River - July 2, 1968							
Diatoms	1	1,992	4,398	5,480	4,432	25,128	4,016
	2	32	140	392	3,528	3,436	2,688
	3	132	0	168	1,720	216	1,560
	4	36	0	169	744	0	272

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm +210	+140	+70	0	-70	-140
	5	40	0	48	272	0	448
	6	8	0	72	24	0	484
Blue-Green Algae	1	14,335	7.968	404	6,262	600	352
	2	665	244	0	1,102	20	144
	3	728	64	12	572	0	6
	4	224	0	48	64	0	12
	5	148	0	96	0	0	0
	6	16	0	108	0	0	30
Green Algae	1	340	44	332	424	176	124
	2	0	20	0	136	48	24
	3	0	0	0	22	20	48
	4	96	0	0	72	0	16
	5	48	0	0	72	0	8
	6	0	0	0	0	0	0
Rhizopods	1	108	156	158	128	60	404
	2	144	0	48	56	36	144
	3	96	0	36	84	4	224
	4	16	8	72	8	0	20
	5	16	16	84	36	0	48
	6	16	8	144	60	0	200
Nematoda	1	172	168	68	56	84	32
	2	36	4	12	8	20	0
	3	36	24	0	12	0	0
	4	24	0	0	0	0	0

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm +210	+140	+70	0	-70	-140
	4	24	0	0	0	0	0
	5	8	8	0	0	0	0
	6	12	8	12	12	0	8
Others	1	56	84	24	32	0	0
	2	48	40	12	32	16	32
	3	0	8	12	24	0	24
	4	0	0	36	0	0	0
	5	8	0	36	36	0	12
	6	0	8	0	0	0	40
C. Wild Rice River, July 16, 1968							
Diatoms	1	9,276	2,408	2,856	7,780	3,360	17,628
	2	12	516	202	638	3,314	616
	3	0	268	64	214	482	128
	4	0	24	180	220	396	68
	5	8	0	108	120	752	16
	6	0	0	82	50	120	4
Blue-Green Algae	1	54,520	31,6[illegible]	5,175	722	48	1,888
	2	0	56	8	10	280	1,600
	3	0	24	0	0	100	240
	4	0	12	0	10	196	136
	5	0	0	24	0	112	32
	6	0	0	0	0	0	0

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm					
		+210	+140	+70	0	-70	-140
Green Algae	1	952	144	144	106	220	328
	2	0	0	24	10	176	8
	3	0	0	24	10	8	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
Rhizopoda	1	252	24	12	40	612	248
	2	48	60	172	60	180	32
	3	0	36	96	30	150	8
	4	0	12	60	40	50	16
	5	8	0	144	10	80	20
	6	0	0	0	0	0	0
Nematoda	1	124	72	60	20	24	0
	2	12	24	0	10	0	16
	3	36	56	12	30	10	0
	4	32	12	12	0	0	4
	5	8	0	0	30	0	0
	6	8	8	0	0	0	0
Others	1	0	0	0	20	24	24
	2	0	0	0	10	20	0
	3	0	0	0	30	60	8
	4	0	0	24	0	0	0
	5	0	0	0	30	0	0
	6	0	0	0	0	0	0

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm					
		+280	+140	+70	0	-70	-140
D. Wild Rice River - July 30, 1968							
Diatoms	1	1,156	5,914	39,260	1,264	7,568	7,712
	2	40	92	264	576	578	6,904
	3	0	36	40	690	502	664
	4	0	20	16	352	376	812
	5	0	0	0	102	272	432
	6	0	0	0	76	102	556
Blue-Green Algae	1	1,236	14,996	8,952	124	483	118
	2	10	10	8	8	108	583
	3	0	36	8	44	50	12
	4	0	0	0	8	16	0
	5	0	20	0	4	0	16
	6	0	0	0	36	28	0
Green Algae	1	16	284	240	24	84	84
	2	0	0	16	96	54	104
	3	0	0	0	330	20	52
	4	0	0	0	80	48	616
	5	0	0	0	16	82	192
	6	0	0	0	8	138	68
Rhizopoda	1	88	60	172	156	240	344
	2	50	40	32	72	180	72
	3	16	156	48	0	220	52
	4	4	120	120	16	68	24
	5	4	90	104	0	258	0

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm +280	+140	+70	0	-70	-140
	6	4	40	100	0	68	0
Nematoda	1	86	70	8	12	10	36
	2	80	0	0	24	0	0
	3	0	24	0	0	0	0
	4	0	0	0	8	0	0
	5	12	0	8	0	0	4
	6	4	0	0	0	0	0
Others	1	0	0	56	24	64	0
	2	10	0	0	0	34	0
	3	0	0	0	0	14	12
	4	0	0	0	0	12	0
	5	0	0	0	0	20	0
	6	0	0	0	0	0	0

E. Wild Rice River - August 14, 1968

		+140	+70	0	-70	-140	-210
Diatoms	1	22,407	166,730	6,560	295,418	86,191	157,184
	2	20	864	84	5,088	2,800	1,268
	3	16	72	160	760	128	1,448
	4	8	32	12	92	116	216
	5	8	50	16	32	72	240
	6	40	56	4	8	88	192

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm					
		+140	+70	0	-70	-140	-210
Blue-Green Algae	1	13,866	1,551	572	12,628	601	3,292
	2	10	6,296	88	197	60	320
	3	10	1,400	20	40	0	144
	4	0	760	0	16	0	68
	5	8	100	0	0	0	60
	6	0	16	0	0	0	16
Green Algae	1	2,204	1,216	68	1,365	252	520
	2	10	20	4	116	44	72
	3	0	4	0	24	128	32
	4	0	0	0	4	44	40
	5	0	0	0	0	0	4
	6	0	0	0	0	16	4
Rhizopoda	1	4	40	8	710	228	456
	2	80	56	28	68	8	80
	3	80	32	12	24	136	20
	4	24	32	8	20	130	0
	5	16	120	16	16	128	12
	6	30	64	20	24	40	16
Nematoda	1	52	8	12	58	24	32
	2	0	0	8	4	4	0
	3	0	0	0	0	0	0
	4	0	0	0	4	0	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm					
		+140	+70	0	-70	-140	-210
Others	1	0	0	20	10	28	64
	2	0	0	0	0	4	8
	3	0	0	0	8	0	12
	4	0	0	0	4	0	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	4

F. Wild Rice River - August 27, 1968

Organism	Depth (cm)	+70	0	-70	-140	-210	-280
Diatoms	1	34,296	10,680	113,848	182,054	18,886	49,763
	2	96	568	5,161	4,494	8,410	4,444
	3	144	88	5,280	3,056	4,652	3,532
	4	16	64	1,200	972	1,104	2,220
	5	30	16	932	576	212	412
	6	64	24	248	1,280	20	36
Blue-Green Algae	1	40,816	2,640	10,828	4,994	4,983	1,000
	2	234	32	5,528	568	658	368
	3	0	0	2,448	480	520	240
	4	0	24	1,500	328	200	200
	5	10	8	364	436	200	16
	6	8	32	208	220	18	64
Green Algae	1	40	120	236	326	550	24
	2	16	8	84	164	200	84

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm +70	0	-70	-140	-210	-280
	3	0	8	112	112	156	60
	4	0	0	24	48	24	44
	5	0	0	24	44	12	8
	6	0	0	8	34	0	0
Rhizopoda	1	160	160	724	490	600	256
	2	96	168	1,140	430	296	108
	3	120	32	56	40	44	76
	4	136	120	20	48	8	56
	5	190	24	36	12	0	44
	6	64	80	64	200	12	36
Nematoda	1	88	16	72	58	30	40
	2	0	0	0	10	0	16
	3	0	0	8	0	8	4
	4	0	0	12	0	0	4
	5	0	0	0	0	4	0
	6	0	0	0	0	0	0
Others	1	0	48	0	40	60	60
	2	0	0	0	20	32	44
	3	0	0	0	0	20	48
	4	0	0	8	0	12	28
	5	0	0	4	0	8	4
	6	0	0	0	10	0	4

G. Wild Rice River - September 21, 1968

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm					
		+70	0	-70	-140	-210	-280
Diatoms	1	4,024	284	39,055	19,636	81,280	147,593
	2	280	48	1,316	2,092	2,968	876
	3	136	72	424	1,240	2,326	200
	4	248	16	88	1,186	880	80
	5	216	44	72	640	600	40
	6	48	0	40	266	160	32
Blue-Green Algae	1	3,080	543	508	936	0	192
	2	150	0	50	40	4	24
	3	36	24	24	16	52	8
	4	0	40	0	8	16	8
	5	372	44	0	32	16	0
	6	0	72	0	16	0	0
Green Algae	1	28	36	282	96	68	128
	2	0	24	28	58	16	20
	3	0	24	8	28	162	56
	4	8	0	0	30	48	0
	5	24	0	0	44	40	4
	6	0	0	0	20	16	0
Rhizopoda	1	36	24	278	636	1,152	184
	2	0	24	130	160	394	40
	3	8	24	24	32	300	48
	4	0	8	16	250	96	16
	5	0	0	24	110	72	12
	6	0	8	32	70	72	56

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm					
		+70	0	-70	-140	-210	-280
Nematoda	1	4	0	50	24	0	0
	2	0	0	0	10	0	8
	3	0	12	0	0	0	0
	4	0	0	0	4	0	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
Others	1	24	0	50	60	48	32
	2	0	0	10	30	8	4
	3	0	0	16	8	40	0
	4	0	0	0	24	32	0
	5	0	0	8	50	16	0
	6	0	0	0	8	0	0
H. Wild Rice River - October 6, 1968							
		+50	0	-70	-140	-210	-280
Diatoms	1	42,330	6,472	5,302	31,593	94,997	592
	2	384	328	3,388	1,905	5,166	104
	3	320	60	916	1,714	548	88
	4	680	8	792	1,472	250	40
	5	232	4	128	472	170	20
	6	68	4	0	344	80	32
Blue-Green Algae	1	5,858	760	630	195	648	24
	2	460	0	126	108	0	0

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm					
		+50	0	-70	-140	-210	-280
	3	375	0	396	91	40	24
	4	2,341	0	12	16	0	0
	5	0	0	0	8	50	0
	6	0	0	0	24	0	0
Green Algae	1	88	12	78	334	144	24
	2	0	0	68	70	180	0
	3	112	0	36	78	32	0
	4	24	0	124	16	0	0
	5	0	0	0	0	10	0
	6	0	0	0	40	0	8
Rhizopoda	1	16	228	300	945	652	72
	2	16	24	572	456	530	32
	3	16	8	384	70	200	24
	4	12	8	124	66	220	28
	5	24	28	40	64	140	34
	6	0	32	N.S.	40	10	16
Nematoda	1	0	0	60	75	14	0
	2	0	0	48	12	20	0
	3	0	0	40	10	0	0
	4	0	0	0	0	0	0
	5	0	0	0	8	0	0
	6	0	0	N.S.	0	0	0
Others	1	36	36	70	120	40	0
	2	32	0	36	12	0	16

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm +50	0	-70	-140	-210	-280
	3	36	36	70	120	40	0
	4	60	0	24	32	10	0
	5	0	0	36	0	10	0
	6	0	0	N.S.	8	0	0

I. Wild Rice River - October 19, 1968

		+18	0	-70	-140	-210	-280
Diatoms	1	138,834	111,559	423,140	66,929	147,576	177,156
	2	52,839	22,998	12,486	30,537	15,870	137,655
	3	128	330	472	3,854	1,888	132,017
	4	86	70	170	2,332	1,368	4,070
	5	110	30	160	3,670	664	810
	6	10	20	130	2,890	128	360
Blue-Green Algae	1	182,844	210,624	64,985	140	180	160
	2	62,182	22,698	272	312	216	328
	3	124	300	12	1,190	108	30
	4	170	40	90	84	56	30
	5	0	0	120	72	0	10
	6	0	0	0	149	24	0
Green Algae	1	192	120	156	132	120	70
	2	132	50	32	76	28	56
	3	0	0	12	72	112	20
	4	8	0	0	8	26	80

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm +18	0	-70	-140	-210	-280
	5	20	0	0	40	48	0
	6	0	0	0	140	0	0
Rhizopoda	1	80	30	1,284	1,032	500	380
	2	180	40	16	350	110	120
	3	96	140	156	394	144	460
	4	90	40	50	732	80	670
	5	0	40	0	564	0	200
	6	0	30	20	400	48	240
Nematoda	1	184	40	36	56	0	50
	2	30	0	40	20	0	40
	3	12	0	0	36	0	20
	4	20	0	0	0	20	0
	5	20	0	0	0	0	20
	6	0	0	0	10	0	20
Others	1	170	30	240	24	28	40
	2	30	10	8	56	10	8
	3	24	0	0	56	0	40
	4	20	0	10	36	0	0
	5	30	0	0	24	0	0
	6	10	0	0	50	8	0

J. Wild Rice River - November 2, 1968

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm					
		+15	0	-70	-140	-210	-280
Diatoms	1	414,712	36,299	198,724	144,180	441,470	207,792
	2	132	312	44,148	44,422	209,524	54,864
	3	168	70	696	648	107,046	40,097
	4	36	24	180	1,496	4,970	8,130
	5	36	12	36	900	2,912	1,900
	6	24	0	64	240	754	620
Blue-Green Algae	1	14,569	37,990	12,713	3,480	1,308	320
	2	168	480	352	168	1,340	80
	3	0	50	12	0	88	46
	4	0	0	0	40	380	170
	5	12	0	24	60	100	60
	6	0	0	0	80	0	70
Green Algae	1	0	24	260	84	94	16
	2	0	8	84	174	94	48
	3	0	10	0	8	100	24
	4	0	0	0	48	30	50
	5	0	0	0	0	88	50
	6	0	0	0	0	66	20
Rhizopoda	1	72	40	480	668	480	96
	2	48	8	108	896	440	248
	3	60	40	24	80	296	240
	4	0	12	80	8	360	740
	5	12	0	168	8	60	480
	6	12	0	4	0	30	50

TABLE 8 - Continued

Organism	Depth (cm)	Distance Relative to Waterline, cm					
		+15	0	-70	-140	-210	-280
Nematoda	1	84	8	24	28	0	72
	2	12	8	0	0	0	32
	3	0	0	12	8	12	16
	4	0	0	0	8	0	0
	5	0	0	0	0	0	0
	6	0	0	0	0	0	0
Others	1	64	24	0	112	70	0
	2	0	8	24	0	38	0
	3	12	0	0	0	72	48
	4	0	0	0	8	10	40
	5	0	0	24	0	8	0
	6	0	0	0	0	0	20

at Stations 2 and 3, and deposition at Stations 1, 4, 5, and 6. Diatom concentrations were high at Station 1, decreased at Stations 2 and 3, and increased again at Stations 4 and 5. They were low also at Station 6, but this was considered to be due to less favorable growth conditions rather than to erosion.

Generic composition varied as follows: (1) The Navicula and Fragilaria groups were the major components of the population at essentially all points along this transect (Table 9a), and (2) Cymbella, Melosira, Gomphonema, Tabellaria, and Amphora were limited to Stations 1, 4, 5, and 6, where medium and finer sands were more common than at Stations 2 and 3. The July 2 patterns appear to show a discrepancy, but a discharge increase at that time affected population composition at Stations 1 and 4.

Numbers showed a decrease with depth in the sand; however, the rate of decline was dependent upon stream processes. Rapid decline was indicative of erosional regions, whereas gradual declines or increases with depth were indicative of depositional zones. Generic diversity at depths below one centimeter remained similar to that of the upper centimeter of sand.

Cyanophyta. On June 13, depositional areas (Stations 4 and 5) had Oscillatoria, Anabena, Merismopedia, and Lyngbya as major population components (Table 9b). But erosional areas (Stations 2 and 3) had only two prevalent genera, Oscillatoria and Lyngbya, or Oscillatoria and Anabena. Oscillatoria and Merismopedia and/or Microcystis dominated blue-greens at depositional Stations 1 and 6. On July 2 and July 16, Stations 4 and 5 had less generic diversity with Anabena, Lyngbya, or Oscillatoria as predominant forms. Station 6 had Lyngbya, Tolypothrix,

TABLE 9

DOMINANT GENERA IN CORES FOR THE MISSISSIPPI RIVER - JUNE THROUGH NOVEMBER, 1968

A. Bacillariophyceae: Genera with 10,000+ Cells per Cubic Centimeter of Sand

Date	Stations							
	1	2	3	4	5	6	7	
June 13	Navicula Group Fragilaria Cymbella Melosira Gomphonema Tabellaria	Fragilaria Navicula Group	Navicula Group Fragilaria Cymbella	Navicula Group Fragilaria Meridion Cymbella Melosira	Navicula Group Fragilaria Cymbella Amphora Gomphonema Tabellaria Melosira	Navicula Group Fragilaria Cymbella Gomphonema		Transect 1
July 2	Navicula Group Fragilaria	Navicula Group Fragilaria	Navicula Group Fragilaria	Navicula Group Fragilaria	Navicula Group Fragilaria Cocconeis Amphora	Fragilaria Navicula Group Amphora Cymbella Tabellaria Gomphonema Melosira		
July 16	Navicula Group Fragilaria Amphora	(1000 or More) Navicula Group Diatoma	(1000 or More) Navicula Group	Navicula Group	Navicula Group Fragilaria Gomphonema			
July 30	Navicula Group Fragilaria Amphora Cymbella	Navicula Group Fragilaria	Navicula Group Fragilaria		(1000 or More) Cocconeis		Fragilaria Navicula Group	Transect 2
Aug. 14	Fragilaria Navicula Group Diatoma Amphora Cymbella	Navicula Group Fragilaria Cocconeis Diatoma Amphora Cymbella	Navicula Group Fragilaria Amphora Cocconeis Diatoma Cymbella		Navicula Group Fragilaria		Navicula Group Fragilaria Diatoma	
Aug. 27	Fragilaria Navicula Group Diatoma Amphora	Navicula Group Fragilaria Cocconeis	Fragilaria Navicula Group Cocconeis Diatoma			Fragilaria Navicula Group Diatoma Amphora Melosira	Fragilaria Navicula Group Diatoma Cocconeis	Transect 2
Sept. 21	Fragilaria Navicula Group Amphora Cymbella	Navicula Group Fragilaria Cymbella Cocconeis Diatoma Amphora Melosira	Fragilaria Navicula Group	Navicula Group Fragilaria Diatoma Cymbella		Navicula Group Fragilaria Diatoma Amphora Melosira		
Oct. 6	Fragilaria Navicula Group Diatoma Melosira Cocconeis Amphora	Fragilaria Navicula Group Diatoma Melosira	Navicula Group Fragilaria Diatoma Cocconeis Melosira Cymbella Amphora	Navicula Group Fragilaria Melosira Cocconeis		Navicula Group Fragilaria Diatoma Melosira Cymbella		
Oct. 20	Fragilaria Navicula Group Diatoma Melosira Amphora Cymbella Cocconeis Gomphonema	Navicula Group Fragilaria Cocconeis Diatoma Cymbella Melosira Amphora	Navicula Group Fragilaria Diatoma Cymbella Melosira Cocconeis		Navicula Group Fragilaria Diatoma Melosira Amphora Cocconeis			Transect 2
Nov. 3	Fragilaria Navicula Group Melosira Diatoma Tabellaria Asterionella Cocconeis Gomphonema Amphora	Fragilaria Navicula Group Melosira Cocconeis Diatoma Amphora Gomphonema Tabellaria	Fragilaria Navicula Group Cocconeis Asterionella Tabellaria Diatoma Amphora Melosira Gomphonema		Fragilaria Navicula Group Diatoma Melosira Tabellaria			

TABLE 9 - Continued

Date	Stations 1	2	3	4	5	6	7	
	B. Cyanophyta: Genera with 100+ Units per Cubic Centimeter of Sand							
June 13	Oscillatoria Merismopedia	Anabena Oscillatoria	Oscillatoria Lyngbya	Oscillatoria Anabena Lyngbya	Oscillatoria Anabena Merismopedia Lyngbya	Microcystis Oscillatoria		Transect 1
July 2	Oscillatoria Lyngbya	Oscillatoria Lyngbya	Oscillatoria	Lyngbya Anabena	Oscillatoria	Lyngbya Tolypothrix Oscillatoria Merismopedia		Transect 1
July 16	Merismopedia Oscillatoria	None Dominate	Oscillatoria	Lyngbya	Oscillatoria Lyngbya			Transect 1
July 30	Oscillatoria Lyngbya Gloeotricha	Oscillatoria Merismopedia	Oscillatoria		Oscillatoria		Lyngbya Oscillatoria Merismopedia Anabena	Transect 2
Aug. 14	Oscillatoria Gomphosphearia Merismopedia	Merismopedia	Merismopedia		Oscillatoria		Oscillatoria	Transect 2
Aug. 27	Oscillatoria Anabena	Merismopedia Gomphosphearia	(None Over 50) Merismopedia			Oscillatoria	Oscillatoria Lyngbya	Transect 2
Sept. 21	Oscillatoria	Merismopedia	None	Merismopedia Oscillatoria		Lyngbya Oscillatoria		Transect 2
Oct. 6	Oscillatoria Merismopedia Anabena Lyngbya Gomphosphearia	Merismopedia Lyngbya	Merismopedia Oscillatoria Microcystis	Oscillatoria Merismopedia Microcystis		Merismopedia Oscillatoria		Transect 2
Oct. 20	Oscillatoria Merismopedia Lyngbya Microcystis Anabena	Merismopedia Anabena	Merismopedia		(None - 100)			Transect 2
Nov. 3	Oscillatoria Chroococcus Merismopedia Microcystis Gomphosphaeria	Oscillatoria Merismopedia Lyngbya Microcystis Chroococcus	Merismopedia Oscillatoria Chroococcus		Oscillatoria			Transect 2
	C. Chlorophyta and Euglenophyta: Genera with 100+ Units per Cubic Centimeters of Sand							
June 13	Scenedesmus Pediastrum Oocystis	Scenedesmus Oocystis	Ulothrix	Scenedesmus Pediastrum Euglena Ulothrix	Scenedesmus Euglena Pediastrum	Pediastrum		Transect 1
July 2	Scenedesmus Pediastrum	Scenedesmus Mougeotia	Scenedesmus	Scenedesmus Peridinium	Scenedesmus	Scenedesmus Pediastrum Cladophora Ulothrix		Transect 1
July 16	Scenedesmus Pediastrum	Cladophora	None in 100 Range	Scenedesmus	Scenedesmus			Transect 1
July 30	Scenedesmus Pediastrum	Scenedesmus Cladophora	(50 or More) Scenedesmus Trachelomonas		Scenedesmus Cladophora		Pediastrum Scenedesmus Microspora Cladophora	

TABLE 9 - Continued

Date	Stations 1	2	3	4	5	6	7	
Aug. 14	Scenedesmus Trachelomonas Pediastrum Closterium Euastrum Crucigenia Cladophora	Cladophora Closterium Pediastrum Trachelomonas Scenedesmus	Closterium Trachelomonas Scenedesmus Crucigenia Peridinium		Trachelomonas		Scenedesmus Trachelomonas Crucigenia Cladophora	Transect 2
Aug. 27	Scenedesmus Trachelomonas Pediastrum	Scenedesmus Trachelomonas	Cladophora Scenedesmus Trachelomonas			Scenedesmus Pediastrum Trachelomonas	Cladophora Pediastrum Trachelomonas	Transect 2
Sept. 21	Scenedesmus Pediastrum Cladophora	Trachelomonas Scenedesmus Cladophora	Trachelomonas	Scenedesmus Trachelomonas		Cladophora Trachelomonas		Transect 2
Oct. 6	Scenedesmus Pediastrum Trachelomonas Oocystis Mougeotia Crucigenia Cladophora	Mougeotia Trachelomonas	Closterium Pediastrum Trachelomonas Cladophora	Trachelomonas		Mougeotia Trachelomonas Scenedesmus		Transect 2
Oct. 20	Scenedesmus Pediastrum Trachelomonas Mougeotia	Trachelomonas Cladophora Scenedesmus	Trachelomonas		Scenedesmus Pediastrum			Transect 2
Nov. 3	Scenedesmus Trachelomonas Cladophora Pediastrum Peridinium	Scenedesmus Trachelomonas Pediastrum Cladophora Peridinium	Trachelomonas Scenedesmus Pediastrum		Scenedesmus Trachelomonas			Transect 2
	D. Animals: Genera with 50+ Individuals per Cubic Centimeter of Sand							
June 13	Centropyxis Hypsibius	Centropyxis Nematoda	Hypsibius Centropyxis	Centropyxis Hysibius Nematoda	Centropyxis Nematoda Monostyla Arcella Aelosoma Hypsibius	Centropyxis Difflugia Nematoda		Transect 1
July 2	Centropyxis Hypsibius Cephalodella	Centropyxis Hypsibius Cephalodella Nematoda	Centropyxis Nematoda	Hypsibius Centropyxis Lepadella	Centropyxis	Centropyxis Difflugia Arcella Nematoda		Transect 1
July 16	Centropyxis	None Hypsibius(32)	Centropyxis	Centropyxis	Centropyxis	No Core		Transect 1
July 30	Centropyxis Difflugia	Centropyxis	Centropyxis Pyxidicula Arcella Euglypha Nebela Difflugia Monostyla Colurella		Centropyxis Difflugia		Centropyxis Difflugia	Transect 2
Aug. 14	Difflugia Centropyxis Arcella Euglypha Colurella	Centropyxis Colurella Difflugia Pyxidicula Monostyla Chaetotonus	Pyxidicula Centropyxis Arcella Monostyla Chaetotonus Trichocerca Nebela Colurella Difflugia Philodina		Difflugia Nebela Euglypha		Euglypha Nebela Centropyxis Difflugia	Transect 2
Aug. 27	Difflugia Centropyxis Nematoda Arcella Pyxidicula Ciliates	Pyxidicula Difflugia Centropyxis Euglypha Loxodes Mites	Arcella Centropyxis Euglypha Difflugia Pyxidicula			Difflugia Centropyxis Euglypha Nebela Arcella Nematoda	Difflugia Centropyxis Nebela Arcella Monostyla	Transect 2

TABLE 9 - Continued

Transect 2

Date	Stations 1	2	3	4	5	6	7
Sept. 21	Difflugia Centropyxis Nebela Arcella Euglypha Cyphoderia Wailesellia Ciliates	Euglypha Centropyxis Arcella Pyxidicula Difflugia	Difflugia Centropyxis	Arcella Euglypha Pyxidicula Centropyxis Difflugia		Euglypha Nebela Arcella Centropyxis Difflugia Cyphoderia Pyxidicula	
Oct. 6	Difflugia Arcella Centropyxis Euglypha Nematoda Pareuglypha Cyphoderia Ciliates	Arcella Difflugia Centropyxis	Arcella Difflugia Euglypha Centropyxis	Arcella Euglypha Centropyxis Cyphoderia Difflugia Pyxidicula Nematoda Ciliates		Ciliates Pyxidicula Centropyxis Arcella	
Oct. 20	Centropyxis Pyxidicula Arcella Difflugia Euglypha Nematoda	Centropyxis Difflugia Arcella Euglypha Pyxidicula Cyphoderia Chironomidae Monostyla	Euglypha Difflugia Centropyxis Arcella Chironomidae		Difflugia Centropyxis		
Nov. 3	Euglypha Pyxidicula Arcella Centropyxis Difflugia Nematoda Cyphoderia	Difflugia Centropyxis Pyxidicula Euglypha Nematoda Wailesella Nebela Cyphoderia Arcella	Arcella Euglypha Pyxidicula Difflugia Centropyxis Nematoda Vorticella		Pareuglypha Difflugia Centropyxis Cyphoderia Nematoda Euglypha		

Oscillatoria, and Merismopedia, but the June dominants were still present at Station 1.

Vertical distribution followed the general pattern shown by diatoms in which the number of individuals decreased with depth unless present in a depositional zone (Table 7). However, some exceptions to this were observed: (1) Stations 2 and 3, when undergoing erosion on June 13, showed increased numbers of Oscillatoria with depth; (2) Station 3 on July 2 had increased numbers of Oscillatoria with depth in the erosion zone; and (3) July 16 showed an Oscillatoria population occurring at some depth in the core at Station 3. Increased Oscillatoria populations at three and four centimeters suggests removal of other genera from upper sand layers prior to depletion of Oscillatoria. Oscillatoria was the only blue-green persisting at greater depths.

Chlorophyta and Euglenophyta. These groups were generally distributed like the diatoms (Tables 7 and 9c). Dominants (100+ individuals per cc of sand) were Scenedesmus, Pediastrum, Oocystis, Cladophora, Mougeotia, Ulothrix, and Euglena. Seasonal and spatial occurrence (Table 9c) illustrate succession and differing degrees of sand stability. Current removal of sand was most common at Stations 2 and 3; deposition formed a ridge at Stations 4 and 5, and was the dominant process at Stations 1 and 6.

Animals. Testaceous Rhizopoda. Rhizopods were generally most numerous in depositional regions (Table 7). Centropyxis was the dominant rhizopod at all times (Table 9d). Arcella and Difflugia, the only other thecamoebae found, were present as indicated in Table 9d. In depositional areas Centropyxis was generally most concentrated in the upper layers. In erosional areas its greatest concentration varied between deep and surface layers (Table 7), which suggests that active migration plays a role in its vertical distribution.

Rotifera. Rotifers were usually localized in the upper three centimeters of sand (Table 7), and their areas of concentration were quite varied. On June 13, greatest numbers occurred in depositional areas, on July 2 erosional zones supported a larger population and on July 16 their numbers were much reduced, but again greatest in depositional areas.

Monostyla dominated the June 13 population (Table 9d); the most prevalent genera on July 2 were Cephalodella and Lepadella; and Philodina and Colurella were the most numerous genera at Station 4 on July 16, when other stations had a mixed composition of small numbers.

Nematoda. From June 13 to July 16 the nematode population steadily declined (Table 7). On June 13, they were most concentrated in upper layers of Station 5 in the depositional zone, but were more abundant at Station 2 in the erosional area than at any of the remaining stations. On July 2 they were most concentrated at Station 6 in a depositional area, and at Stations 2 and 3 in the area being eroded. On July 16 their numbers were few, but greatest at Station 4 in the depositional region. They seemed to prefer the upper sand layers, but occasionally were found to six centimeters.

Tardigrada. Hypsibius sp. was the only tardigrade found. It occurred only once at Station 6 (Table 7). There was a gradual decrease in numbers from June 13 to July 16. Greatest concentration was found on June 13 at Station 3 in the erosion zone, but a shift to deposition Stations 1 and 4 had occurred by July 2, and a small, but more uniformly distributed, population was present on July 16.

Other Animals. Oligochaeta, Cladocera, Chironomidae larvae, Gastrotricha, and Ostracoda comprise this category. They were found in the upper two centimeters and decreased in numbers from June 13 to July 16, at which time only a few remained (Table 7). Oligochaetes were found only on June 13, at which time they were the major constituent of this group. No specific animal dominated this population on other dates.

Transect 2

Both exposed and submerged sand were available for study when sampling was changed to this location on July 30. The exposed point bar (Station 1) was composed of sand, largely of medium grade, whereas the exposed region on the left bank (Station 5) was mainly gravel (Figures 7 and 8). The sand surface at Station 1 was always wet, but the surface of the coarser sand at Station 5 was dry because of a lower capillary potential.

Algae. Bacillariophyceae. On July 30, Station 1 was at the waterline; from August 14 through October 6 it was exposed to the air; and from October 19 through November 3 it was again submerged.

The diatom population at Station 1 on July 30 was dominated by the Navicula group, Fragilaria group, Amphora, and Cymbella (Table 9a). Diatoma joined the dominant groups on August 14, and through October 6 a quartet or more of these diatoms accounted for most of the population. The Fragilaria group outnumbered the Navicula group at some or all stations in August, and maintained its dominance in at least one station until November 3. The Navicula group regained dominance in some areas in September and October. Greater stability of sand resulting from exposure led to greater concentrations of diatoms in its upper layers (Table 7). Light penetration is limited to the first few millimeters, and without the disrupting influences of erosion or deposition, diatoms were confined to the more favorable upper regions of the core.

The autumn submergence of the point bar was accompanied by an increase in diversity and numbers, and by greater population in deeper sand regions. The Fragilaria group, Navicula group, Diatoma, Melosira, Amphora, Cymbella, Cocconeis, and Gomphonema all achieved domiant rank on October 19. Asterionella replaced Cymbella on November 3.

Station 5 on the left bank was exposed from July 30 to August 27, and was at the waterline from September 21 to October 6. The Navicula and Fragilaria groups were dominant here on July 30, but with continued exposure, Diatoma and then Cocconeis also became prevalent. Generic composition remained about the same, but numbers decreased rapidly with depth. Return of the waterline to Station 5 resulted in a downward movement of diatoms into the second centimeter and a larger number of dominant species.

Stations 2, 3, and 4 were continually submerged. Station 2 was always 70 cm from Station 1; Station 3 was always 70 cm from Station 2; and Station 4 was located at various distances along the transect, depending upon where the sand would permit coring.

Station 2 had a smaller but more variable population than did Station 1. The Navicula group dominated this station longer, and larger numbers occurred at greater depths in the sand. Except for July 30 and November 3, Station 2 was influenced in part by erosional, and in part by stable, conditions. Details of its biota on November 3 will be given later. Except for these two dates, its population decreased with depth.

The generic composition of the population varied from a co-dominance by the Navicula and Fragilaria groups to a complex of eight dominant forms:

the *Fragilaria* group, *Navicula* group, *Melosira*, *Cocconeis*, *Diatoma*, *Amphora*, *Gomphonema*, and *Tabellaria*.

The population of Station 3 was usually reduced by erosion, at which times numbers decreased with greater depth. Make-up of the population, seldom the same from date to date, involved an assortment of groupings from bi-dominant *Fragilaria-Navicula* groups to a multi-dominant complex of *Fragilaria* and *Navicula* groups, *Cocconeis*, *Asterionella*, *Tabellaria*, *Diatoma*, *Amphora*, *Melosira*, and *Gomphonema*, showing no particular successional pattern.

The smallest population was at Station 4, where current erosion appeared most severe. Numbers declined with depth and dominance ranged from a single form, *Cocconeis*, on July 30, to *Navicula-Fragilaria* groups on August 14, to these two groups plus *Diatoma*, *Cymbella*, *Melosira*, *Cocconeis*, and *Tabellaria* in varying ranks (Table 9a).

Cyanophyta. On July 30, dominant genera varied at different stations as shown in Table 11. They occurred at most depths, but were evidently most concentrated near the surface in stable sand (Table 7). Under currents (Station 3) they occurred at greater depths. Over the remainder of the sampling period, blue-greens exhibited no consistent pattern. Occasionally they were most concentrated near the surface in stable sand, but at times occurred with greatest numbers in the erosional zone; whereas some were restricted to the surface zone, others penetrated to a depth of six centimeters (Table 7d-j). Dominance varied among a number of groups (Table 9b) with *Oscillatoria* tending to outnumber others in the autumn and in more stable sands. *Microcystis* and *Chroococcus* entered when sand again became submerged.

Deposition resulted in occurrences at greater depths, but in eroded and stable sands, blue-greens were generally concentrated in the upper two centimeters. Erosion completely removed blue-greens from Station 3 on September 21, but they were relatively highly concentrated there at later dates.

Chlorophyta and Euglenophyta. Dominance among green algae and euglenophytes was held by the groups appearing in Table 9c. Their numerical distribution tended to follow the diatom pattern, although they were much less abundant. They responded to erosion, deposition, and stable conditions in much the same manners as diatoms and blue-greens, as is indicated by their horizontal and vertical distribution in Table 7d-j. Return of the waterline to a previously exposed position brought about qualitative changes (Table 9c).

Animals. Testaceous Rhizopoda. This group was the major segment of the animal population, with rather substantial numbers generally all along the transect (Table 7). The greatest concentration noted was in coarse materials at Station 5, but this area did not consistently have more than others. Centropyxis was the most prevalent form when sampling began on this transect, but others were more numerous in later samples as shown in Table 9d. However, Centropyxis was among dominants in all but one sample. In addition to this genus, dominant rank was achieved by Difflugia, Pyxidicula, Arcella, Euglypha, Nebela, Pareuglypha, Cyphoderia, and Wailesella. Water level variation, sand deposition, and erosion were determinant factors in the establishment of these genera as dominants (Table 9d). Some forms (Pyxidicula, Nebela, Cyphoderia, Wailesella, and Pareuglypha) became more prominent as exposed sand "aged", whereas others (Centropyxis, Euglypha, and Arcella) appeared to prefer water-filled sand. Testaceous rhizopods as a group penetrated to the deepest sampled sand layers, and were occasionally more numerous there than in upper sands (Table 7d-j). This may result from deposition or migration.

Rotifera. Rotifers were frequently restricted to the top two centimeters of sand but they did occur at greater depth on depositional sites (Table 7). They were less prevalent in the gravel-dominated sediments of Stations 4 and 5, but did occur there. Monostyla, Colurella, and Trichocerca were the most abundant genera. Their times and locations as dominant groups are shown in Table 9d. Exposure of sand evidently caused a decrease of Colurella at Station 1.

Nematoda. Nematodes were generally limited to the upper three centimeters of sand, with apparent preference for more stabilized sand (Table 7). Finer sand and increased stability at Station 1 supported a steady population over most of the sampling period. Stations 2, 3, and 4 supported only small populations unless they were the sites of depositional activity, such as Station 2 on November 3. Numbers at Station 5, while small, continued to increase with age of exposure, but they declined when the waterline returned to the vicinity.

Tardigrada. Tardigrades were localized in the upper two centimeters of the cores unless the station was in a depositional zone. Station 1 was almost completely lacking in Hypsibius after exposure. Stations 2, 3, and 4 varied from time to time, often having no Hypsibius, and whereas only "strays" occurred at Station 5.

Other Animals. Oligochaeta, Copepoda, Dipteran larvae, Gastrotricha, Ostracoda, Acari, and Ciliophora comprise this category in Table 7. These organisms were confined to surface or near surface sand cores unless in a deposition area.

Wild Rice River

Algae

Bacillariophyceae. The smallest population usually occured at the 0 cm station (Table 8). The Navicula group dominating this station (Table 10a) was located in the upper two centimeters, with small populations lingering in deeper layers.

Exposed Sand Region. Sand 70 centimeters above the waterline generally had the largest diatom populations found in exposed sand. The Navicula group was dominant there, except on October 19, when Rhopalodia shared dominance. Diatoms diminished rapidly with depth, but Surirella often persisted in small numbers down to six centimeters.

The population declined at 140 cm above the waterline, where Rhopalodia and the Navicula group were the prevalent genera in small numbers. Again with the exception of Surirella, diatoms were limited to the uppermost centimeter of sand. At distances greater than +140 cm, diatoms continued to decline, being restricted to near surface sand, with Rhopalodia or the Navicula group forming the bulk of the small populations.

Submerged Sand Region. Numbers frequently increased between the waterline and the sand 70 cm below it, where they were sometimes greater, but often less, than at +70 cm. Small eddy currents frequently eroded sand at -70 cm, and it then contained fewer diatoms than sand beyond it. This was not always true, but it appeared that the smaller populations in submerged sand usually marked the locations of currents. Diatoms attained their maxima in the uppermost centimeter, but they occurred in greater numbers deeper in the sand than they did on the exposed beach.

TABLE 10

DOMINANT GENERA IN CORES FOR THE WILD RICE RIVER - JUNE THROUGH NOVEMBER, 1968
DISTANCES RELATIVE TO WATERLINE WHICH DIFFER FROM HEADING IN PARENTHESIS

A. Bacillariophyceae: Genera with 10,000+ Cells per Cubic Centimeter of Sand - Smaller numbers in parentheses

Date	Distance Relative to Waterline (cm)							
	+210	+140	+70	0	-70	-140	-210	-280
June 13	Navicula Group (700)	Navicula Group (2,000)	Navicula Group	All Less Than 50	Navicula Group (2,600)	Navicula Group Diatoma Melosira Fragilaria		
July 2	Rhopalodia (1,200)	Rhopalodia (2,000) Navicula Group (1,400) Fragilaria (1,000)	Navicula Group (4,500)	Navicula Group (3,000) Rhopalodia (1,300)	Navicula Group	Navicula Group (3,400)		
July 16	Navicula Group (5,400) Rhopalodia (3,800)	Navicula Group (2,000)	Navicula Group (2,600)	Navicula Group (6,600)	Navicula Group (2,000) Surirella (1,000)	Rhopalodia Navicula Group (6,800)		
July 30	Rhopalodia (200) (280cm)	Navicula Group (5,300)	Navicula Group	Navicula Group (600)	Navicula Group (5,300)	Navicula Group (6,800)		
Aug. 14		Navicula Group	Navicula Group	Navicula Group (5,400)	Navicula Group Cocconeis	Navicula Group	Navicula Group	
Aug. 27			Navicula Group	Navicula Group (8,400)	Navicula Group	Navicula Group Gyrosigma Amphora	Navicula Group (8,500) Diatoma (5,700)	Navicula Group Cymbella
Sept. 21			Navicula Group (3,800)	Navicula Group (200)	Navicula Group	Navicula Group	Navicula Group Diatoma (5,200)	Navicula Group Cymbella Amphora
Oct. 6			Navicula Group (50cm)	Navicula Group (3,800)	Navicula Group (2,100) Surirella (1,000)	Navicula Group	Navicula Group Amphora	Navicula Group (400)
Oct. 20			Navicula Group Rhopalodia (18cm)	Navicula Group	Navicula Group Diatoma Amphora	Navicula Group Amphora	Navicula Group Diatoma	Navicula Group Amphora Diatoma Cymbella
Nov. 3			Navicula Group (15cm)	Navicula Group	Navicula Group Diatoma Amphora Cymbella	Navicula Group Diatoma (6,600)	Navicula Group Diatoma Amphora	Navicula Group Amphora Cymbella Diatoma

TABLE 10 - Continued

B. Cyanophyta: Genera with 100+ Units per Cubic Centimeter of Sand

Date	Distance Relative to Waterline (cm)							
	+210	+140	+70	0	-70	-140	-210	-280
June 13	Oscillatoria	Anabena Oscillatoria	Oscillatoria Anabena Microcystis	Lyngbya (60)	Oscillatoria	Oscillatoria		
July 2	Oscillatoria Anabena Chroococcus Nostoc	Oscillatoria	Oscillatoria	Oscillatoria Anabena	Oscillatoria	Oscillatoria		
July 16	Oscillatoria Microcoleus Anabena	Oscillatoria Anabena	Oscillatoria Anabena	Oscillatoria	Oscillatoria	Oscillatoria		
July 30	Oscillatoria Nostoc Microcoleus (280cm)	Oscillatoria Anabena	Anabena Oscillatoria Lyngbya	Oscillatoria (90)	Oscillatoria	Oscillatoria Anabena		
Aug. 14		Oscillatoria Anabena	Oscillatoria	Oscillatoria	Oscillatoria Anabena Merismopedia	Oscillatoria	Oscillatoria	
Aug. 27			Oscillatoria Microcoleus Anabena	Oscillatoria	Oscillatoria Lyngbya	Oscillatoria	Oscillatoria	Oscillatoria
Sept. 21			Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria (30)	Oscillatoria
Oct. 6			Oscillatoria Microcoleus Lyngbya (50cm)	Oscillatoria	Oscillatoria	Oscillatoria	Oscillatoria Anabena	Oscillatoria (24)
Oct. 20			Oscillatoria Anabena Lyngbya Chroococcus Nostoc (18cm)	Oscillatoria Anabena	Oscillatoria Nostoc	Oscillatoria Chroococcus	Oscillatoria	Oscillatoria
Nov. 3			Oscillatoria (15cm)	Oscillatoria	Oscillatoria	Oscillatoria Chroococcus	Oscillatoria	Oscillatoria

TABLE 10 - Continued

C. Chlorophyta and Euglenophyta: Genera with 100+ Units per Cubic Centimeters of Sand

Date	Distance Relative to Waterline (cm)							
	+210	+140	+70	0	-70	-140	-210	-280
June 13	Euglena(32)	Scenedesmus Euglena	Pediastrum(50)	Absent	Absent	Scenedesmus Pediastrum		
July 2	Vaucheria Euglena (24)	Scenedesmus	Scenedesmus	Scenedesmus Vaucheria	Euglena (80)	Closterium (48) Euglena (44)		
July 16	Vaucheria	Vaucheria	Euglena	Euglena	Scenedesmus	Scenedesmus		
July 30	Scenedesmus (16) (280cm)	Euglena	Scenedesmus	Scenedesmus Pediastrum	Pediastrum (50)	Scenedesmus		
Aug. 14		Euglena	Scenedesmus Stigeoclonium	Scenedesmus (25)	Scenedesmus Closterium Stigeoclonium Cladophora	Scenedesmus Stigeoclonium	Scenedesmus Stigeoclonium	
Aug. 27			Euglena (24)	Euglena (50)	Closterium	Closterium Stigeoclonium	Cladophora Closterium	Stigeoclonium
Sept. 21			Scenedesmus (28)	Euglena (36)	Stigeoclonium	Stigeoclonium	Stigeoclonium	Cosmarium
Oct. 6			Stigeoclonium (70) (50 cm)	Absent	Cosmarium (80)	Stigeoclonium Pediastrum	Stigeoclonium (80) Oocystis (80)	Cosmarium (16)
Oct. 20			Scenedesmus (18cm)	Scenedesmus (40)	Scenedesmus (70)	Scenedesmus	Scenedesmus (68)	Stigeoclonium (60)
Nov. 3			Absent (15cm)	Euglena (16)	Oocystis	Stigeoclonium	Stigeoclonium (40)	Stigeoclonium (40)

TABLE 10 - Continued

Date	D. Animals: Genera with 50+ Individuals per Cubic Centimeter of Sand							
	Distance Relative to Waterline (cm)							
	+210	+140	+70	0	-70	-140	-210	-280
June 13	Nematoda Centropyxis	Nematoda	Nematoda Centropyxis	Centropyxis (24)	Centropyxis	Centropyxis Arcella Difflugia		
July 2	Nematoda Centropyxis	Nematoda Centropyxis	Centropyxis Nematoda	Centropyxis Nematoda	Nematoda Centropyxis	Centropyxis Difflugia		
July 16	Centropyxis Nematoda	Nematoda Centropyxis	Centropyxis Nematoda	Centropyxis	Centropyxis Difflugia	Centropyxis Difflugia		
July 30	Difflugia Nematoda (280cm)	Difflugia Nematoda	Difflugia	Difflugia Centropyxis	Difflugia	Difflugia		
Aug. 14		Difflugia Nematoda	Difflugia	Difflugia (30)	Difflugia Nematoda	Difflugia	Difflugia	
Aug. 27			Difflugia Nematoda	Difflugia	Difflugia Centropyxis Nematoda	Difflugia Centropyxis	Difflugia Centropyxis	Difflugia Centropyxis
Sept. 21			Difflugia (32)	Difflugia (24)	Difflugia Centropyxis Nematoda	Difflugia Centropyxis	Difflugia Centropyxis	Difflugia
Oct. 6			Difflugia (50cm)	Difflugia	Difflugia Centropyxis Nematoda	Difflugia Centropyxis Nematoda	Difflugia Centropyxis	Difflugia
Oct. 20			Nematoda Difflugia Centropyxis (18cm)	Difflugia	Difflugia Centropyxis	Difflugia Centropyxis Nematoda	Difflugia Centropyxis	Difflugia Centropyxis Nematoda
Nov. 3			Difflugia Nematoda (15cm)	Difflugia (24)	Difflugia	Difflugia Centropyxis	Difflugia Centropyxis	Difflugia Centropyxis Nematoda

The Navicula group was the most numerous diatom in submerged sand until October 19 when Diatoma and Amphora became abundant (Table 8). Cymbella entered dominant ranks on November 3.

Cyanophyta. At the beginning of sampling, this group had its greatest abundance on the beach, usually +140 cm above the waterline. This continued until August 14, when substantial numbers appeared at -70 cm and beyond (Table 8). In September and early October there was a decline in numbers, with beach stations having the larger populations. A great increase was evident on October 19, with highest numbers at waterline, and this pattern was noted again on November 3, although numbers were much smaller. The -70 cm station was well populated on these dates.

Seasonal variations in dominant genera at different stations is shown in Table 10b. Oscillatoria was the chief dominant except on three occasions involving two stations. Other dominants may be noted in the table.

Blue-greens were often restricted to surface sands, but at times occurred in appreciable numbers at depth down to four centimeters both above and below the waterline. Those present at greater depths have been buried by deposition, and those in deeper sand above water probably reflect exposure of a submerged depositional area. In this regard, blue-greens appear to be more tolerant than diatoms.

Chlorophyta and Euglenophyta. Distribution and density of green algae and euglenophytes varied throughout the study. Their inconsistency can best be domonstrated by reference to Table 8. Dominance among them was shared by Scenedesmus, Euglena, Pediastrum, and others as appears in Table 10c.

Animals

Testaceous Rhizopoda. This group was dominated by Centropyxis and Difflugia, whose relative abundance over the seasons and transect appears in Table 10d. Their numbers varied with distance from the waterline and depth into the sand as is shown in Table 8. Initial populations at the waterline were sparse but increased with time.

Nematoda. This group was most abundant on the beach +70 cm above the waterline, with only three exceptions (Table 8), when it was most numerous at -70 cm.

Other Animals. Rotifera, Chironomidae larvae, and occasional Ostracoda and Tardigrada occurred in small numbers and were localized in the upper centimeters.

Effects of Deposition on Population Dynamics

On November 3, Station 2 on the Mississippi River transect was sampled, having recently received a new sand deposit which added three centimeters atop the old sand (Figure 11). Vertical distribution of the potamopsammon population at Station 2 on that date (Table 11) may be compared with that at the same site on October 19 (Table 12). The surface centimeter of October 19 was the fourth centimeter on November 3, and it still contained the large numbers of organisms that had developed in surface sand. The new sand brought in numbers of organisms that were mixed in the upper three centimeters, but they were usually less numerous than in the older established sand. A planktonic form, Asterionella, present in the new sand, had not occurred in the older sand, and Cymbella and Cladophora were more numerous in new sand. Greater numbers of

TABLE 11

VERTICAL DISTRIBUTION OF ORGANISMS IN A NEWLY FORMED SANDBAR AT STATION 2 OF THE MISSISSIPPI RIVER - NUMBERS ARE PER CUBIC CENTIMETER OF SAND

Organism	Depth (cm)					
	1	2	3	4	5	6
Navicula Group	19,397	28,889	211,477	271,555	57,778	1,640
Fragilaria	35,905	16,508	165,080	469,651	85,842	7,360
Melosira	2,380	21,460	63,556	181,588	23,111	1,240
Tabellaria	4,480	2,920	16,508	10,050	8,254	720
Asterionella	2,200	2,320	880	0	0	0
Amphora	120	360	9,905	24,350	9,905	72
Diatoma	60	120	9,079	41,683	240	480
Cymbella	100	120	9,079	700	0	32
Cocconeis	180	1,000	26,413	57,778	2,160	160
Gyrosigma	440	160	200	92	0	0
Gomphonema	80	120	6,603	20,635	24	24
Oscillatoria	220	440	11,557	33,176	16	0
Merismopedia	240	0	2,000	26,858	0	0
Gomphosphaeria	0	0	32	108	32	0
Microcystis	6	16	48	168	0	0
Chroococcus	8	72	0	428	0	0
Lyngbya	0	0	680	1,300	0	0
Trachelomonas	180	80	240	700	144	8
Scenedesmus	16	32	5,778	8,274	240	40
Pediastrum	4	16	160	108	8	0
Cladophora	0	0	4,280	3,100	576	0
Euglena	0	0	0	32	0	0
Phacus	0	0	0	32	0	0
Peridinium	4	4	24	100	0	0
Centropyxis	10	0	120	400	96	16
Difflugia	18	20	120	600	64	12
Pyxidicula	8	24	120	540	48	8
Euglypha	4	0	48	332	64	16
Arcella	16	16	160	316	64	16
Cyphoderia	14	16	64	60	16	8
Wailesella	0	4	32	108	0	0
Nebela	0	0	56	16	0	0
Nematoda	70	64	96	216	32	8
Monostyla	18	16	8	0	16	0
Colurella	6	0	16	20	0	0

TABLE 12

VERTICAL DISTRIBUTION OF ORGANISMS IN SAND OF STATION 2 OF THE MISSISSIPPI RIVER BEFORE BEING COVERED WITH SANDBAR REFERRED TO IN TABLE 11 - NUMBERS ARE PER CUBIC CENTIMETER OF SAND

Organism	Depth (cm)					
	1	2	3	4	5	6
Navicula Group	338,410	80,889	40,445	29,714	720	200
Fragilaria	297,140	52,000	20,735	29,714	1,640	560
Diatoma	44,572	15,683	200	80	120	12
Cocconeis	37,968	8,254	160	120	204	0
Cymbella	29,714	9,905	400	120	56	24
Melosira	26,413	1,600	560	400	120	28
Amphora	21,460	8,254	360	200	120	12
Gyrosigma	560	24	12	0	8	0
Gomphonema	320	8	24	12	4	0
Tabellaria	240	120	32	64	0	120
Merismopedia	31,365	120	56	60	0	0
Anabena	312	0	0	0	0	0
Oscillatoria	0	12	0	0	0	16
Chroococcus	0	32	0	0	0	0
Scenedesmus	240	120	32	56	0	8
Trachelomonas	400	48	32	16	8	0
Pediastrum	40	68	32	0	0	12
Cladophora	280	0	0	0	0	0
Centropyxis	208	60	56	20	20	40
Difflugia	152	32	12	16	24	24
Euglypha	144	20	0	0	0	0
Arcella	104	120	0	8	0	8
Pyxidicula	72	8	4	0	4	0
Cyphoderia	48	0	0	0	0	4
Nematoda	32	4	0	8	0	0
Monostyla	56	0	8	0	0	0
Colurella	16	0	0	0	0	0
Trichocerca	16	0	0	0	0	0

organisms in the third centimeter of new sand may reflect a disturbance of the older surface which momentarily suspended organisms, or drove them down through the looser new sand, or both.

DISCUSSION

Physical Features

Sand

Sand exercises great control over the potamopsammon assemblage, since its texture determines pore space, capillary potential, and water-holding capacity. Arrangement of sand grains delimits the amount of interstitial space, which determines the amount of potential living room, the amount of water held therein, and the capillary potential.

Sand composed of uniformly-sized spheres would have an interstitial space volume of 25.96% (Bruce, 1928a and Ruttner-Kolisko, 1962). Previous workers (Sassuchin, et al., 1927; Pennak, 1940; Neel, 1948; and Ruttner-Kolisko, 1962) found ungraded beach sand to have from 37% to 43% pore space. This divergence from the theoretical value can be attributed to angularity of the sand which prevents optimal packing. Reduction of interstitial space as determined in this study of the Mississippi River sand (22%-25%) was caused by a variety of grades, which allowed more complete packing. The Wild Rice River, with better sorted sand, had 35%-37% pore space.

Bruce (1928a) reported a capillary rise for ungraded marine beach sediments of 260 to 268 mm after two hours. Pennak (1940) and Neel (1948) found capillary rise in ungraded lake beach sand to vary from 63 to 89 mm after 24 hours. The Mississippi River sand showed somewhat greater variation than that found by Pennak and Neel, 36 to 80 mm after 24 hours.

Finer sand of the Wild Rice River produced readings intermediate to those of marine and lake beaches, 118 to 191 mm after 24 hours. Height of capillary rise along with slope of beach determines the lardward extent of the psammon above waterline. Influences of slope, as effective in beach dynamics of both marine and freshwater beaches, have been previously discussed by Pennak (1940), Neel (1948), Ruttner-Kolisko (1956, 1961) and Jansson (1967a).

Temperature

Jansson (1967b) described temperature relationships of a marine beach, whereas those for freshwater beaches have been presented by Sassuchin, et al. (1927), Pennak (1940), and Neel (1948). Meteorological conditions which affect both insolation and evaporation determine temperature relationships between free water, interstitial water, and beach sand. Beach sand in direct sunlight will absorb heat to the extent that organisms could not survive. However, due to the high latent heat of vaporization of water (539.55 cal/gm), the moist sand remains very stable in its temperature regime, provided sufficient water is available at the surface for evaporation.

Organic Matter

Pennak (1940) stated that two general types of dead particulate organic matter occur in beach sands, one a finely divided debris, and the other consisting of larger particles such as bits of leaves, twigs, aquatic vegetation, and insect remains. The incorporation of this material into the beach by waves was described by Neel (1948). Particulate organic matter accumulated in exposed and submerged sands of small streams is not mixed into sand by wave action. Deposition of such material reflects variation in current patterns. This is suggested by variation in organic content with depth in both the Wild Rice and Mississippi Rivers (Table 5). The Mississippi River sand ranged from 105 to 217 mg organic matter/10cc of sand. Pennak (1940) found the range for lake beaches to be from 0.3 to 15.3 mg/10cc of sand, and only when a sample was taken from a recent windrow of wave-accumulated debris did the lake values (128.7 mg/10cc of sand) approach those of the streams.

Chemical Features

Chemistry of Interstitial Water

Interstitial water from depths of 6 to 9 cm is not considered representative of that in the upper layers of sand which contain the bulk of potamopsammon populations. It does, however, permit speculation regarding conditions in more superficial layers.

Oxygen

Marine beaches, as a result of frequent and often massive wave action, develop measurable oxygen concentrations some distance above the waterline. Brafield (1964) found oxygen levels varying from 3.93 to 0.26 ml/liter, depending upon percentage of fine sand, existence of a black layer, and depth of sampling. Jansson (1967c) and Enckell (1968), using a platinum microelectrode, found oxygen concentrations ranging from 9.83 to 0.0 mgl, the determinative factors being grain size, slope, particulate organic matter, and frequency of a black layer.

Pennak (1940, 1951), Neel (1948), and Ruttner-Kolisko (1956) reported that the waterline region, which was subject to frequent wave action, contained 5.5, 3.5, and 8.0 mgl, respectively. Further shoreward, concentrations dropped abruptly, Pennak and Neel reporting a maximum of 0.4 mgl and Ruttner-Kolisko, a maximum of 3.5 mg.

Ruttner-Kolisko (1961) presented data on the oxygen content of stream beaches in Austria, but only on exposed regions. She reported variations of from 12.5 to 7.0 mgl in interstitial water at the waterline. Decline with distance above waterline was sometimes progressive (8.0 mgl at the waterline to 1.0 mgl 50 cm above it), and sometimes discontinuous (10.0 mgl at the waterline, 2.5 mgl at 30 cm, and 7.0 mgl at 50 cm). With the exception of August 14, 1968, oxygen was not found above waterline in either Mississippi or Wild Rice River beaches or bars. The submerged fine sands of the Wild Rice River contained no oxygen, whereas the coarser submerged sands of the Mississippi River had small amounts (up to 4.4 mgl) until August 20, 1968.

Abundance of life in upper layers of exposed sand strongly suggests the presence of oxygen. It may be absorbed from the atmosphere and supplied by photosynthesis.

Hydrogen Ion Concentration

Pennak (1940) and Neel (1948) reported that the pH of interstitial water of lake beaches was lower than that of the lake water. A situation existed in the sands of the streams studied, and may be attributed to influx of ground water and/or decomposition of organic matter in the sand.

Alkalinity

Carbonate alkalinity was found only in stream water of both rivers. There was a progressive increase in bicarbonate alkalinity from stream to submerged sand to exposed sand for each river (Tables 6a,b). Greater amounts in interstitial water resulted from concentration by evaporation on the beach, from probable ground water entry into submerged sand, and by the dissolution of marl by CO_2 formed by decomposition. Similar data were reported by Ruttner-Kolisko (1961) for the Ybbs River in Austria, which is comparable to the Mississippi in alkalinity. A shoreward increase in alkalinity has been reported for lakes by Pennak (1940) and Ruttner-Kolisko (1956). Neel (1948), however, found higher bicarbonate alkalinity occurring in the submerged regions of Douglas Lake, due to formation of bicarbonate from marl deposits.

Total Hardness, Calcium, and Magnesium

Increases of total hardness, calcium, and magnesium occurred from the stream to submerged to exposed sand, and varied with discharge. Decrease in discharge was accompanied by uniform hardness values for the three regions, possibly indicating the flux of ground water. Disparity among the regions with increasing duration of low discharge resulted from evaporation of interstitial water and photosynthetic activity.

Phosphate and Ammonia-Nitrogen

Influence of drainage basin on streams is illustrated by phosphate and ammonia-nitrogen concentrations. The Wild Rice River drained predominately agricultural land, and, in the immediate vicinity of the station, a feedlot. This environment accounted for concentratiions considerably above those of the Mississippi River, which drained bog and forest land.

Black Layer

Sassuchin et al. (1927), Bruce (1928b), Pennak (1940, 1951), Neel (1948), Brafield (1964), and Fenchel (1967) reported the development of a black layer in the beach sands of oceans, lakes, and streams. Jansson (1968) noted the absence of this black layer in several Swedish marine beaches. No black layer or its accompanying hydrogen sulfide odor was found in either the exposed or submerged sands of the two rivers in this study, even in cores extended to a depth of 25 cm. In the laboratory, hydrogen sulfide gas was bubbled through sand samples; the sand developed a black color which indicated the presence of iron oxide coating the sand grains.

Biological Features

Life forms comprising the potamopsammon are motile or sessile. Algae are predominantly motile forms, as indicated by the great number of motile diatoms. A similar association, the epipelic association of Round (1957c) was also dominated by motile species. He noted that mobility is a prime necessity in order to overcome burial during periods of wave and animal-induced disturbances of sediment. Diatoms may be borne on mucilagenous stalks (e.g., Gomphonema spp.) or attached directly to sand grains (e.g., Achnanthes spp.). Stalked forms were more susceptible to washing and recovery from sand. Attached species, when present, were not easily dislodged by washing, but sand grains bore very few of them.

Potamopsammon Compared to Lake Psammon

The psammon of Douglas Lake, Michigan, was composed of 255 different species of algae and animals (Neel, 1948), of which 89 were found in the potamopsammon of the Mississippi and Wild Rice Rivers. Table 13 summarizes the quantitative data presented by Neel. Maximum population levels were attained in the upper centimeter of relatively undisturbed sand. Organisms seldom occurred below the six centimeter depth.

Distribution of potamopsammon had many similarities to that of lake psammon. Exposed sands of both streams had organisms concentrated in the upper centimeters of sand. Submerged sand showed more variation, with algal populations occurring mainly in the upper centimeters one week, in the intermediate layers (3-5 cm) the next, and uniformly distributed throughout the 6 cm core the next. Animals with greater mobility apparently moved to the upper layers. Causative agents of this variable distribution were sand erosion and deposition, which were dependent upon current patterns. Neel (1948) noted that concentration of organisms in deeper layers (3-5 cm) of sand resulted from formation of beach ridges by onshore waves. On one occasion an alongshore current increased the population of deeper layers in submerged sand. Generally such currents depopulated sand.

Pennak (1940) and Ruttner-Kolisko (1956) described the microscopic interstitial fauna of the beaches of several Wisconsin lakes and an Austrian lake; respectively. Of the 71 different animals found in Wisconsin beaches, only 14 were present in the potamopsammon. Ruttner-Kolisko listed 11 different animals of which 4 were present in these two streams.

TABLE 13

SUMMARY OF THE RANGE OF QUANTITATIVE DATA FOR THE FIRST CENTIMETER OF THE SAND FOR DOUGLAS LAKE, MICHIGAN; NUMBER OF PSAMMON ORGANISMS PER CUBIC CENTIMETER OF SAND

Location	Diatoms	Cyanophyta	Chlorophyta	Rhizopoda	Rotifera	Nematoda	Tardigrada
Exposed Sand	500 to 288,200	30 to 677	9 to 134	3 to 1011	0 to 69	0 to 96	0 to 27
Water Line	160 to 325,900	5 to 292	0 to 43	0 to 219	0 to 62	0 to 114	0 to 5
Submerged Sand	300 to 270,400	2 to 768	0 to 371	0 to 295	1 to 83	0 to 139	0 to 26

Source: Neel, J. K. 1948. A limnological investigation of the psammon in Douglas Lake, Michigan, with especial reference to shoal and shoreline dynamics. Trans. Am. Microc. Soc. 67: 1-53.

Table 14 summarizes data of Pennak and Ruttner-Kolisko regarding horizontal location of main faunal groups. The Mississippi and Wild Rice Rivers had representatives of all these groups, except the harpacticoid copepods. The rotifer fauna of the two streams was much less diverse than that of Douglas Lake and the Wisconsin lakes.

Pennak described the vertical distribution of major animal groups as follows: tardigrades varied from existing solely in the upper two centimeters to being uniformly dispersed to a depth of eight centimeters; copepods were restricted to the upper four centimeters of the sand; rotifers were found in the upper two centimeters of both submerged and exposed sand; and flagellated protozoans were most abundant in the uppermost centimeter of sand.

The tardigrade, <u>Hypsibius augusti</u>, and the copepod <u>Parastenocaris phyllura</u>, were the two dominant interstitial animals in the beach sand of three Swedish lakes (Enckell, 1968). This is the only previous report of <u>Hypsibius</u> in the psammon fauna.

Moore (1939) found animals in moderate numbers to a depth of four to five centimeters in the profundal benthos of Douglas Lake, Michigan, whereas Cole (1955) reported that 70 to 90% of the animals in the micro-benthos of Lake Itasca and Crystal Lake, Minnesota were in the uppermost centimeter.

Round (1957a, b, and c, 1960, and 1961), listed 86 species of algae as comprising the epipelic population of some English lakes. Thirty of these were found in the potamopsammon of the Mississippi and Wild Rice Rivers. Round stated that Bacillariophyceae were most abundant on sediments high in organic matter (30.8%) and calcium (780 mgl), and that Cyanophyta were generally more abundant on sediments poor in

TABLE 14

SUMMARY OF THE HORIZONTAL AND NUMERICAL DISTRIBUTION OF THE MICROFAUNA OF SEVERAL WISCONSIN LAKES AND AN AUSTRIAN LAKE; NUMBER OF ORGANISMS PER CUBIC CENTIMETER OF SAND

Location	Wisconsin Lake Beaches					Austrian Lake Beach				
	Tardigrada	Cepepoda Harpacticoida	Rotifera	Protozoa (Euglenoids)	Nematoda	Protozoa (Ciliata)	Rotifera	Nematoda	Oligocheata	Harpacticoida
Exposed Sand	0 to 41	0 to 27	0 to 1155	200 to 50,000	0 to 14	4000	500	30	10	Less Than 10
Waterline	0 to 1	0 to 1	0 to 40	. . .	. .	. .	. .	. .	. .	. .
Submerged Sand	0 to 1	0	0 to 5	. .	. .	. .	. .	. .	. .	. .

Source: Pennak, R. W. 1940. Ecology of the microscopic metazoa inhabiting the sandy beaches of some Wisconsin lakes. Ecol. Monogr. 10: 538-615.
Ruttner-Kolisko, A. 1956. Der Lebensraum des Limnopsammals. In, Verh. dt. Zool. Ges. im Hamburg 1956, Akademische Verlagsgesellschaft Geest and Portig K.-G., Leipzig, pp. 421-427.

diatoms, or having low organic matter (14.7%) and calcium (370 mgl) content. This may appear to explain dominance change from diatoms to blue-green algae in exposed sand of the Wild Rice River, but the change was more the result of less capillary water.

The general lack of Cyanophyta, Chlorophyta, Pyrrophyta, and Euglenophyta species in the epipelic association led Round (1957c) to assume that the benthic habitat is unsuited for these groups. Chlorophyta, Pyrrophyta, and Euglenophyta were not represented by a great variety of species in the Mississippi and Wild Rice psammon, but on occasion attained substantial numbers. The Cyanophyta, not prominent in lake psammon, was represented by substantial numbers of motile species in both streams.

The potamopsammon did not exhibit obvious cyclic patterns; there were no gradual build-ups but continual variation, as stream currents were constantly disturbing the habitat. The Bacillariophyceae and the Cyanophyta of the epipelic association exhibited a seasonal cycle. Round (1960 and 1961) summarized it as follows: a low winter growth, high spring growth, variable summer growth, and moderate autumn growth.

Round (1965) reported 18 species of diatoms attached to sand grains in the sediment of four English ponds. Six of these were present in the Mississippi and Wild Rice potamopsammon.

A detailed comparison of potamopsammon as exhibited by the Mississippi and Wild Rice Rivers with lake psammon as described by Pennak (1940), Neel (1948), and Ruttner-Kolisko (1956) follows. The Mississippi River possessed a wider range of sand grades than was reported for lakes, since it flowed through an area composed of glacial till. As a consequence of this greater variety, the unsieved sand of the Mississippi River possessed less pore space than has been reported for lakes, and the capillary potential of this sand was generally lower than that reported for lakes. The Wild Rice River with a more uniform sand composition, possessed an ungraded sand pore space approximately equal to that of lakes. This uniformity produced a capillary potential considerably higher than that of either the Mississippi River or lakes. The content of organic matter in stream sand was higher than in lake sand except for beach ridges. Submerged sand of the streams, unlike that of lakes, was constantly under the influence of currents. Furthermore, wave action was an insignificant force in establishing sand grade at the waterline which is not true for lake sand. The potamopsammon environment (submerged and exposed sand) was subject to more pronounced and varied water level fluctuations. Marl was a component of Wild Rice River sand, as it was for some areas in Douglas Lake. Temperature relationships were similar to those in lakes.

Interstitial water was collected from a greater depth than was reported by Neel (1948). Less oxygen was present in both the submerged and exposed sand than was reported for lakes, due to the sampling depth. The pH and alkalinity were similar to those of lakes, with increases shoreward resulting from decomposition and evaporation. Total hardness, calcium, magnesium, ortho-phosphate, ammonia-nitrogen, and nitrite-nitrogen, given here, have not been reported for lakes. A black layer was absent in the upper 25 cm of sand in both streams, whereas in lakes this layer usually separates oxygenated and deoxygenated zones. A possible explanation for the lack of this layer may be a more rapid replacement of the interstitial water, preventing the establishment of a reducing environment for bubbling of hydrogen sulfide gas through moist sand in the laboratory resulted in a definite black layer.

Of the 236 different psammon organisms in the Mississippi River 71 were present in lakes; the Wild Rice River potamopsammon was composed of 178 different organisms, 47 of which were common to lake psammon. Cyanophyta species were more numerous in these streams than in lakes. Euglenophyta were present in potamopsammon, but Pennak (1940) only briefly noted their existence in lake psammon. Harpacticoid copepods were absent in the streams, although they were a characteristic group in the lake assemblage. Bacillariophyceae, Cyanophyta, Chlorophyta, Euglenophyta, and testaceous Rhizopods were found in greater numbers per cubic centimeter of sand than in lakes. Rotifera, Nematoda, Tardigrada, Gastrotricha, Dipteran larvae, and Oligochaeta were generally found in numbers similar to those of lakes. Substantial populations occurred in submerged sand with greatest numbers being found in depositional ridges of the stream, whereas submerged sand in lakes was less well colonized. Smallest populations occurred generally at the waterline of the streams, but the largest populations in lake psammon often occurred at this location. Exposed sand populations for streams were generally larger than those at the waterline, but populations declined with distance from water. Shoreward reduction in numbers was also reported for lakes.

The Mississippi River exposed sand developed little slope and exhibited no shoreward change in flora or fauna, whereas the exposed beach of the Wild Rice River had a significant slope, and established a saturation gradient from the waterline shoreward. A succession of algae followed this gradient with diatoms dominating the saturated portion, and was replaced by blue-green algae in less saturated regions. The potamopsammon fauna did not show a shoreward succession but a succession of animals, not algae, was noted in lake psammon. Stability of the exposed sand for both streams allowed the potamopsammon organisms to disperse freely. This resulted in algae populations being located predominantly in the upper two centimeters of sand, but with viable cells extending to a depth of six centimeters as compared with one centimeter for undisturbed lake sand. Animals dispersed similarly to algae, but had a more uniform distribution in the deeper layers, as reported in lakes. Downward movement of potamopsammon organisms was not impeded by an anaerobic black layer as has occurred in lakes.

Comparison of Minnesota Rivers and European Rivers

The following algae were reported as being dominant in the Oka River sand (Sassuchin et al., 1927): Navicula radiosa, N. crytocephala, Nitzschia palea, Phormidium sp., Oscillatoria tenuis, Chlamydomonas sp., and Scenedesmus quadricauda. Sassuchin found psammon organisms existing to a depth of ten centimeters, and reported that buried organisms remained viable up to two weeks.

Butcher (1932) listed 23 genera and 22 species of Bacillariophyceae, Cyanophyta, and Chlorophyta, all of which were sessile, for several English rivers. Of these, 17 genera and 14 species were part of the Mississippi River and Wild Rice River psammon assemblages.

Neiswestnova-Shadina (1935) found that the microbenthos of the Oka River completely lacked a microflora. She attributed this to high turbidity which prevented light penetration beyond 80 cm. In sandy shallow regions, reduced currents permitted deposit of a thin layer of mud atop the sand. Light penetrated to this area and the development of a rich microflora, composed mainly of diatoms, but including also green flagellates, Protococcales, and Volvocales, resulted. Neiswestnowa-Shadina listed 81 different animal species (41 protozoans, 28 rotifers, 9 cladocerans, etc.), few of which occurred in the psammon of the Mississippi and Wild Rice Rivers. A typical quantitative sample she described contained 80 rotifers, 38 protozoans, and 4 oligochaetes per cubic centimeter of sand.

Douglas (1958) found maximum populations of the attached *Achnanthes* sp. (5.1×10^6 cells/cm^2) on stone or rock surfaces in a small English stream. Water level fluctuations were the most important factors influencing this *Achnanthes* population. Physical disturbance of the stream bottom by increased flow simply removed diatoms from their attached surfaces.

Flow pattern variations were also effective in population dynamics of the potamopsammon, removing organisms from interstitial spaces and redepositing them elsewhere, generally at a different depth.

Ruttner-Kolisko (1961) described only general animal groups (ciliates, rotifers, etc.) present on Austrian river beaches. Quantitative data were not given, but she stated that only sand from 2.0 to 0.2 mm in grain size was capable of supporting a psammon association. The Donau River beach was composed of 90% fine sand (0-250 μ), and was sparsely colonized only in the upper three centimeters. The Langau station on the Ybbs River, having 28% of the sand as medium sand (250-400 μ) and lacking fine sand, exhibited the greatest animal diversity. Colonization on this beach reached a depth of six centimeters. Other stations were intermediate in sand composition and colonization.

Mississippi River sand was similar to that of the Ybbs and it supported an equally diverse animal association down to a depth of six centimeters. Sands of the Wild Rice River were comparable with those of the Donau River; and animal diversity was equally limited, although organisms occurred to greater depths in the Wild Rice. With decreased discharge, exposed sand became more heterogeneous, containing a larger percentage of medium grades. Accompanying this change was an increase in diversity of both algae and animals. While this does not substantiate Ruttner-Kolisko's hypothesis that sand below 0.2 mm grain size is incapable of supporting an interstitial flora (organisms were found in fine sand), the increase in diversity with more heterogeneous sand would support her general thesis.

Sassuchin et al. (1927) stated that a vertical cut in the sand near the stream revealed four characteristic color layers: the upper surface was unstained; the second stratum was green due to development of massive algal populations; the third stratum was brown, arising from accumulation of silt and formation of iron oxides; and the fourth layer was black. This pattern was not exhibited by the Mississippi and Wild Rice Rivers. Their sand surface layers were brown due to massive populations of diatoms, and neither had a green layer. Diatoms colored the upper few centimeters of Mississippi River cores, and marl imparted a grey color to Wild Rice River sand below the first centimeter. As mentioned previously, the black layer did not exist in either river.

Round (1965) described phytobenthos as being composed of four distinct associations: (1) the epiphytic: attached non-motile species growing mainly on macroscopic plants; (2) the epilithic: attached non-motile species growing on rock surfaces and inorganic substrata; (3) the epipelic: motile species found on the sediments of freshwater; and

(4) the epipsammic: small non-motile species attached specifically to sand grains. In this system, the potamopsammon would be termed an epipelic association with an epipsammic component. But an epipelic association implies an assemblage of algae on the surface of a highly organic mud or silt deposit. This was not the situation with potamopsammon as organisms occurred to a depth of several centimeters in both exposed and submerged sands of streams. There was an epipsammic component, if this association is not restricted to surface sand grains, of occasional small diatoms attached to sand grains in the two streams. Thus, I view the potamopsammon as a separate entity from the four situations described by Round.

Migration

It has been mentioned that mobility is advantageous for the potamopsammon microflora, allowing escape from burial. This could imply migration of these algae. Palmer and Round (1965) described the following occurrence on the banks of the River Avon: During the daytime at low tide, the exposed banks of the river developed a green color, owing to a massive population of *Euglena obtusa*, which emerged from the black mud.

Round and Palmer (1966) indicated that a diatom population was associated with the *Euglena*. Both populations exhibited a rhythmic vertical migrational pattern. In the laboratory, the vertical migration continued for almost a month, even after being subjected to constant illumination and temperature, and isolated from the tidal influence. The rhythm changed from a tidal to a diurnal period. Various intensities of constant illumination altered the amplitude of the rhythm, but not the periodicity. Total darkness inhibited the rhythm. The rhythm was also inhibited at 2°C, but between 5 and 15°C there was no alteration.

The epipelic algae of a freshwater pond also demonstrated vertical migration under three different sets of conditions: natural light/darkness, continuous light, and continuous darkness (Round and Eaton, 1966). Round and Happey (1965) found that the epipelic flora of a stream would migrate under laboratory conditions. Harper (1969) established that epipsammic diatoms migrate, but more slowly than epipelic diatoms.

With the potamopsammon microflora having representatives of both the epipelic and epipsammic associations, the probability of vertical migration from deeper layers to surface and vice-versa exists, and could be an important factor in the distribution of the assemblage. No direct evidence was collected, however, which would demonstrate the existence of vertical migration on either the Mississippi or the Wild Rice Rivers.

SUMMARY

1. Potamopsammon reported herein represents the upper Mississippi and middle Wild Rice Rivers which drain bog-forests, and bog-forests followed by cultivated lands, respectively.

2. Sands of the Mississippi River were coarser than those of the Wild Rice River, and had less pore space and capillarity. Submerged sand was frequently eroded and deposited by currents.

3. Oxygen was absent from water 6-9 cm deep in exposed sand of both streams and in submerged sand of the Wild Rice River, but occasionally occurred in samples taken from submerged sand in the Mississippi; pH decreased progressively from stream to submerged to exposed sand as decomposition became more localized. Carbonate alkalinity was not observed in interstitial water. Bicarbonate alkalinity, total hardness, calcium, and magnesium increased in the same order as pH, seemingly because of ground water seepage, decomposition, and evaporation.

4. Ammonia-nitrogen and ortho-phosphate were contributed to the psammon of the Wild Rice River by local surface drainage. Much lower levels occurred in Mississippi River sand.

5. Potamopsammon organisms in descending order of dominance were: diatoms, blue-green algae, green algae, testaceous rhizopods, euglenophytes,

rotifers, nematodes, tardigrades, dinoflagellates, oligochaetes, gastrotrichs, dipteran larvae, ciliates, ostracods, and hydrachnid larvae.

6. Potamopsammon organisms were most numerous in stable submerged sand. They were next most abundant in exposed sand within 70 cm of the waterline, newly formed sand bars under water, eroded portions of submerged sand, exposed sand 70+ cm above the waterline, and at the waterline, in that order.

7. The major portion of the population was usually located in the upper two centimeters of stable sand, but organisms penetrated to a depth of six centimeters. Organisms were most concentrated at a depth of three or more centimeters in newly formed submerged bars usually as a result of burial of established surface populations.

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