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A Study of the Vertical Distribution of Periphyton Diatoms in Lake West Okoboji, Iowa[1]

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Abstract. A series of five stations, arranged as a bottom transect away from shore between the depths of 15 centimeters and 5 meters, was studied. During the three-month period of study (June, July, and August, 1964) there was an evident seasonal succession of dominant diatom species at all stations. In general, the greatest fluctuations in the dominant elements of the flora were noted in the shallower stations. Besides being more seasonally stable, the floras of the deeper stations were relatively more diverse on all dates sampled.

The ecology of periphyton algae has evoked the interest of numerous investigators. It is widely recognized that diatoms are an important element in most such communities. Aleem (1949, 1950) has investigated naturally occurring communities in a littoral zone of the British coast. Castenholz (1960) has investigated the seasonal changes in periphyton communities in fresh and saline lakes in the western United States and has (1963) conducted experimental investigations of the seasonal colonization rates of marine littoral diatoms. Blum (1956) reviewed the literature concerning such communities in lotic environments, and more recently Sládecková (1962) has provided an excellent review of the methods used in periphyton investigations. In reports of his investigations of primary productivity in periphyton communities, Wetzel (1964, 1965) has reviewed the literature particularly pertinent to productivity investigations.

The aims of the present investigation were to determine the depth distribution of dominant periphyton diatom species and the fluctuations in their relative abundance over relatively short time periods. Our previous observations led us to believe that both the species composition and the absolute quantity of diatom biomass in periphyton communities fluctuated widely during different periods of collection and at different collection depths.

METHODS

The area selected for study was a bottom transect running due west from the southern tip of Fort Dodge Point on Lake West Okoboji, Iowa. This area has a steeply sloping bottom that is uniformly covered with glacial cobbles and boulders down to a depth of about 9 meters. By use of free diving apparatus, hand samples were taken at depths of 15 centimeters, 1, 2, 3, 4 and 5 meters. The stations selected were sampled on 20 June, 19 July, and 6 August, 1964. On the latter two sampling dates the temperatures at each station

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sampled were recorded, and water samples for chemical analysis were taken at the shallowest and at the deepest stations sampled.

After recovery the biological samples were split. One-half of each sample was preserved in standard formalin-acetic acid-alcohol preservative and retained as a reference collection. The remaining portion of each sample was "cleaned" by the method of Van der Werff (1956). Permanent slides suitable for identification of the diatom species present were then made using Hyrax as a mounting medium. Measurements of the frequency of dominant diatom species were obtained by identifying and recording all specimens in random oil immersion (1000X) fields. Counts were continued until a total of 500 specimens had been identified from each slide.

Water samples taken in conjunction with this study were returned to the laboratory and analyzed within one hour after collection.

Results

Collection 1 was made on June 20, 1964. Although the water temperature was not recorded, there was no temperature discontinuity perceptible to divers working in the area within the depth sampled. There was a perceptible temperature discontinuity at the depth of 9 meters. At this time a luxuriant growth of *Cladophora* covered the rocks at all depths sampled.

Frequency of the diatom species recovered from these samples is shown in Table 1. To facilitate discussion those species which comprised less than 5 percent of the total flora have been placed together in the "rare" category, and their cumulative frequencies rather than the frequency of each species is recorded. It will be noted that there is relatively little differentiation of the flora with depth in these samples. *Cocconeis pediculus* is abundant at all depths although its abundance does drop rather strikingly at the 5-meter depth. The total number of species per sample and, concomitantly, the percentage contribution of the rare species tend to increase with depth.

Table 1

Frequency of Diatom Species in Samples Taken 20 June.
Where no numerical figure is given the frequency is less than 5 percent.

	Frequency in Percent					
Sample Depth	15 cm.	1 m.	2 m.	3 m.	4 m.	5 m.
Cocconeis pediculus Ehr.	43	87	55	47	73	15
Gomphonema olivaceum (Lyngb.) Kütz.	43	—	25	29	—	—
Synedra vaucheriae (Kütz.) Peters.	8	—	5	—	—	—
Cymbella prostrata (Berkeley) Cleve	—	—	—	9	—	—
Achnanthes sp.	—	—	—	5	—	—
Rhoicosphenia curvata (Kütz.) Grun.	—	—	—	—	7	—
Fragilaria intermedia (Grun.)	—	—	—	—	6	5
Amphora ovalis var. *pediculus* Kütz.	—	—	—	—	—	18
Nitzschia dissipata (Kütz.) Grun.	—	—	—	—	—	6
Rare species (cumulative total)	6	13	15	10	14	56
Total number of species counted per sample	8	11	9	13	22	65

Collection 2 was taken on July 19, 1964. The floristic results from this series of samples are presented in Table 2. Temperature and water chemistry data for this sample are recorded in Table 3. It will be noted that the thermocline has developed between 4 and 5 meters. During this sampling period it was noted that *Cladophora* was absent from the 4- and 5-meter stations and that the plants which occurred at the other sampling depths appeared depauperate. The differentiation of the flora with depth is somewhat better developed than in the first series of samples. The most striking discontinuity appears to occur between the 3- and 4-meter stations. This difference is reflected both in the frequent elements of the flora and in the total species composition.

Table 2

Frequency of Diatom Species in Samples Taken 19 July.
Where no numerical figure is given the frequency is less than 5 percent.

	Frequency in Percent					
Sample Depth	15 cm.	1 m.	2 m.	3 m.	4 m.	5 m.
Cocconeis pediculus Ehr.	69	84	86	65	—	—
Synedra vaucheriae (Kütz.) Peters.	11	—	—	—	—	—
Epithemia turgida (Ehr.) Kütz.	—	—	—	12	—	—
Amphora ovalis var. *pediculus* Kütz.	—	—	—	—	21	18
Fragilaria intermedia Grun.	—	—	—	—	18	13
Stephanodiscus niagarae Ehr.	—	—	—	—	—	5
Rare species (cumulative total)	20	16	14	23	61	64
Total number of species counted per sample	18	15	18	21	80	80

Table 3

Temperature and Water Chemistry; Collection II.

	15 cm.	1 m.	2 m.	3 m.	4 m.	5 m.
Temperature	27° C.	27° C.	26° C.	25° C.	25° C.	22° C.
Alkalinity (total)	197 ppm ($CaCO_3$)					193 ppm ($CaCO_3$)
(P)	12.5 ppm					11.2 ppm
Total hardness	212 ppm ($CaCO_3$)					210 ppm ($CaCO_3$)
Iron	None detected					None detected
Nitrate	0.009 ppm					0.04 ppm
Nitrite	0.016 ppm					0.09 ppm
Phosphate (total as PO_4)	0.26 ppm					0.16 ppm
Sulfate	26 ppm					31 ppm
pH	8.68					8.66

Collection 3 was taken on August 6, 1964 (Table 4). Physical and chemical data taken at this time as shown in Table 5 reveal substantial alteration in the environment. It will be noted that the water is isothermal at all depths sampled and that there is a small net decrease in surface temperature and an appreciable increase in temperature at the 5-meter depth relative to the previous sampling date. Probable cause for this is to be found in the very heavy rains which occurred approximately one week before the date of sampling and which caused a net rise in lake level of approximately 15 centimeters. Another heavy rain fell two days before the time of sampling. Floristic data from this series of samples indicate further differentiation of the flora with depth. In most cases there is a definite peak frequency of occurrence at a particular depth.

Table 4

Frequency of Diatom Species in Samples Taken 6 August. Where no numerical figure is given the frequency is less than 5 percent.

	Frequency in Percent					
Sample Depth	15 cm.	1 m.	2 m.	3 m.	4 m.	5 m.
Gomphonema olivaceum (Lyngb.) Kütz. ..	28	—	—	—	—	—
Synedra acus Kütz.	60	—	—	—	—	—
Cocconeis pediculus Ehr.	—	38	21	7	—	—
Epithemia turgida (Ehr.) Kütz.)	—	6	38	5	—	—
Amphora ovalis var. *pediculus* Kütz.	—	5	—	12	31	15
Gomphonema gracile var. *aurita* (A. Braun Cleve)	—	—	6	23	9	—
Epithemia sp.	—	—	—	10	5	—
Rhoicosphenia curvata (Kütz.) Grun.	—	—	—	6	10	6
Fragilaria intermedia Grun.	—	—	—	—	5	18
Cocconeis placentula Ehr.	—	—	—	—	—	15
Navilcula scutelloides Wm. Smith	—	—	—	—	—	5
Rare species (cumulative total)	12	51	35	37	40	41
Total number of species counted per sample	14	45	35	41	54	60

Table 5

Temperature and Water Chemistry; Collection III.

	15 cm.	1 m.	2 m.	3 m.	4 m.	5 m.
Temperature	26° C.	26° C.	26° C.	26° C.	26° C.	26° C.
Alkalinity (total) .	197 ppm					195 ppm
(P) ...	12 ppm					10 ppm
Total hardness ...	200 ppm					204 ppm
Iron	None detected					None detected
Nitrate	0.25 ppm					0.045 ppm
Nitrite	0.009 ppm					0.014 ppm
Phosphate (total as PO_4) ..	0.10 ppm					0.18 ppm
Sulfate	23 ppm					28 ppm
pH	8.64					8.59
Silica	8.0 ppm					8.0 ppm

Discussion

Perhaps a salient feature of our results is the consistently increasing diversity of the diatom flora with increasing depth. In all instances the highest total number of species and the highest percentage contribution to the total flora by rare species were found at the deepest stations sampled. This result is reasonable in terms of physical factors of the environment. An organism living at greater depths should be less subject to drastic changes in temperature and solar radiation and is effectively insulated from the destructive effects of wave action. It would also appear that at least in this particular environment the diatom species are less subject to competition from other algal groups which are less well adapted to growing under conditions of low ambient light.

The competition factors are aptly illustrated in the case of *Cocconeis pediculus*. This organism is particularly well adapted to epiphytic growth upon *Cladophora*. As previously noted, the latter alga was the visible dominant during the periods of collection. It would appear, however, that the adaptation to epiphytic growth on this particular substrate carries with it the penalty of less successful growth at a greater depth. In all instances *Cocconeis pediculus* reached its greatest abundance between the depths of 1 and 2 meters, and it was rarely abundant below the depth of 4 meters. Once the over-riding habitat preference influence of *Cladophora* was removed, as in the third series of samples, a greater diversity in the abundant elements of the diatom flora appeared together with an apparent depth preference for most of the abundant species. Examples of this may be seen in *Amphora ovalis* which occurred in all samples and was consistently most abundant between 4 and 5 meters depth, and in *Rhoicosphenia curvata* which was most abundant at a depth of 4 meters.

Although observations cover only the mid-summer months of June, July, and August, some indications of the normal seasonal succession of dominant diatom species in this habitat are evident. Our previous observations have shown that *Gomphonema oblivaceum* is the visible dominant in this habitat during the spring and fall months. A remnant of this spring flora is still present in the June collections but is completely absent in the July collections. It would appear that the fall flora is beginning to establish itself in the August collections. Previous observations would lead us to believe this to be unusual in terms of the normal seasonal succession in Lake West Okoboji, and this instance may be attributable to the premature early upset of summer stratification by the previously mentioned unusual weather conditions. The rise in lake level associated with unusually heavy rains is reflected in the overwhelming dominance of *Synedra acus* in the shallow station of the third series of collections. This species together with the recently established *Gomphonema olivaceum* comprised nearly 90 percent of the flora at this station.

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