Phytoplankton Community Ordination at a Site in Extreme Southern Lake Michigan

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Introduction

The phytoplankton community existing in the extreme southern basin of Lake Michigan near Michigan City, Indiana, was evaluated from June 1973 to May 1974 using principal components ordination analysis. This analysis is a mathematical technique that can reduce a large volume of data to a simplified objective presentation (10). Qualitative and quantitative phytoplankton data are used as "loading factors" to calculate ordinal placement values for each sample included in the analysis (7). A graphical display of the principal components can visually depict similarities and differences within the community. This exercise enabled temporal variabilities over the period of study, and the spatial limitations in this portion of Lake Michigan, to be evaluated. Although numerous studies investigating seasonal changes and spatial differences have been completed on Lake Michigan since 1872 (2,6,14,17,18,19,20), ordination analysis was typically not applied.

A number of community ordination techniques exist, each having a specific application (1,10,21). Orloci (10) notes that principal components is the most efficient of ordination techniques because it maximizes data point spread. Pielou (12) indicated it is the most straightforward of many possible techniques, but some authors note that mathematical calculations are more difficult than other methods (4,10). Although the limitations of principal components ordination technique have been noted (4,10,12), its application to community analysis is beneficial in interpretation of results.

Study Area

Eight stations were located in Lake Michigan on three transects near Michigan City, Indiana. Stations 1-4 were located 1770 m east of the Michigan City lighthouse at depths of 5, 10, 15, and 18 m, respectively, on Michigan City transect (M). Stations 5 and 6 were located at 5 and 15 m depths on the Dunes transect (D) 2800 m west of the lighthouse near the dune known as "Old Baldy." Stations 7 and 8 were located on a transect about 3470 m west of the harbor lighthouse near the mouth of Kintzele Ditch (K). McComish (9) described the transects and study area in detail.

Methods

Field and Laboratory

One-liter water samples for phytoplankton analysis were collected at about monthly intervals at stations in Lake Michigan from June 1973 to May 1974.

Samples were collected at the surface in wide mouth polypropylene bottles and preserved with merthiolate solution (23).

Plankton samples in the bottles were allowed to stand and settle in the laboratory for a minimum of two weeks. Samples were aspirated to about 40 ml and remaining settled plankton concentrate was placed into a 150 ml container. Aspirated supernatant was passed through a Foerst centrifuge to collect any organisms not settled out, and the centrifugate was then added to the sample concentrate. Samples were subsequently adjusted to standard 100 ml volume by adding preservative. Three 1 ml subsamples were taken from each sample concentrate with a Hensen-Stemple pipet and each was placed into a Sedgewick-Rafter counting chamber. Three strips representing 20% of the counting chamber volume were counted at 160X magnification. Non-diatoms were enumerated and identified to species when possible, while diatoms were counted and recorded as only pennate or centric for application of a proportional count. Permanent slides were prepared for indentification of diatoms in each sample following the procedure outlined by Weber (23). A total of about 500 diatoms were identified for each sample using a Zeiss Nomarski interference contrast microscope at 1000X magnification. The individual species tally was then applied to the proportional Sedgewick-Rafter cell count following Weber's (23) methods. Taxonomic keys for phytoplankton identification included Prescott (13), Patrick and Reimer (11), Weber (24), Drouet and Daily (3), Smith (16), and Tiffany and Britton (22).

TABLE 1. *Species used in the principle components ordination analysis*

Species
Bacillariophyta
Asterionella formosa
Cyclotella glomerata
Cyclotella meneghiniana
Cyclotella michiganiana
Cyclotella ocellata
Diatoma tenue var. *elongata*
Fragilaria crotonensis
Fragilaria intermedia
Melosira islandica
Melosira italica
Navicula cryptocephala
Navicula exigua
Nitzschia palea
Nitzschia sublinearis
Stephanodiscus astraea
Stephanodiscus binderanus
Stephanodiscus hantzschii
Stephanodiscus minutus
Stephanodiscus tenuis
Synedra ulna
Tabellaria fenestrata
Tabellaria flocculosa
Thalassiosira fluviatilis
Chlorophyta
Ankistrodesmus falcatus
Lagerheimia ciliata
Scenedesmus dimorphus
Scenedesmus quadricauda
Sphaerocystis schoeteri
Cyanophyta
Chroococcus limneticus

Ordination

Principal components ordination as described by Orloci (10) was employed in community evaluation of the phytoplankton assemblage. Since the analysis is not sensitive to small populations, and the intent of the ordination is to show major community direction (Ladewski, per. comm.) only "major" species were included in the analysis. The species selected occurred in at least 25 percent of the total samples and had a minimum population of 6/ml in a single sample. This eliminated 197 of the 226 taxa identified in the study. Loading factors, or input data, of these 29 species (Table 1) were based on percentage, not actual densities, in an effort to normalize the data from the 85 samples used.

The first three ordinal values were calculated, and displayed graphically, using the X, Y, and Z axes. Mathematical computations were completed at the University of Michigan Computing Center using programs supplied by the Great Lakes Reserach Division, the University of Michigan.

Results

Principal components ordination analysis using the first and second components shown on X and Y axes, respectively, revealed a clumping of stations, based primarily on temporal cycling (Figure 1). Three major seasonal groups were defined: June-September, October-January, and March-May. Only minor trends were noted for spatial differences. Each major season grouping had additional variability revealed by the third component, represented by the Z axis (Figure 1). Although not as significant as the first or second component values, in some instances the third component separated individual stations within a group. A relatively small number of species were responsible for the major groupings as well as influencing some of the lesser differences found within each defined season. Other

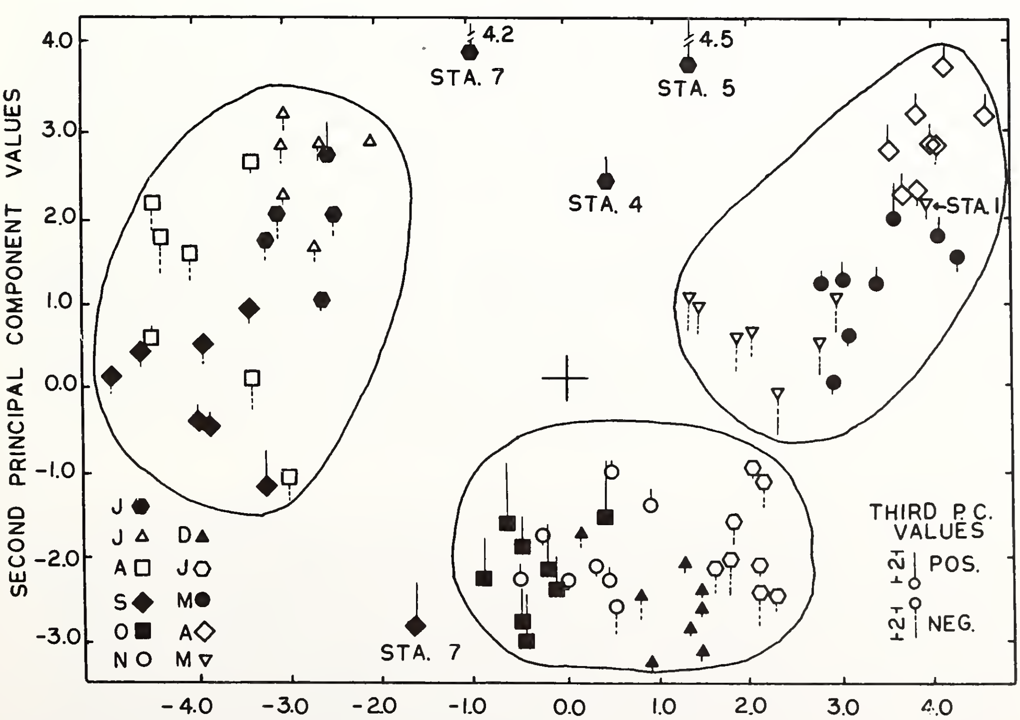

FIGURE 1. *First Principal Component Values*

less dominant species did not significantly affect definition of the community but could have accounted for some of the minor differences found between and within months.

June-December Grouping

The occurrence of *Thalassiosira fluviatilis* had the most profound effect on the ordination of the summer community. High populations of this diatom were found in June at stations 1, 2, 3, 6, and 8 with densities ranging from 25 to 74% of the total community. Absence of this species at stations 4, 5, and 7 was a primary factor causing ordinal displacement of these stations (Figure 1). Additionally, *Stephanodiscus binderanus, S. hantzschii, S. minutus and Ankistrodesmus falcatus* had distinctly higher populations at stations 4, 5, and 7 than the remaining five stations in June. *Cyclotella meneghiniana* and *Nitzschia palea* populations appeared notably higher at stations 1, 2, 3, 6 and 8 during this period, however. On the basis of both examinations of the raw data and the ordination analysis, two communities existed in June.

Thalassiosira fluviatilis and *Cyclotella glomerata* dominated all stations in July. Ordinal placement of stations during this period reflected similar population values for all samples. Continued dominance by *T. fluviatilis* in August ordinated these samples near earlier summer ones as expected. Minor changes during this time, however, were principally due to the absence of *C. glomerata* (a July dominant), and the strong appearance of *Chroococcus limneticus* and *Lagerheimia cilata.*

In September, *Thalassiosira fluviatilis* again dominated, but not at all stations. Station 7 showed relatively high populations of *Melosira italica, Fragilaria crotonensis* and *Tabellaria flocculosa.* Almost insignificant in this sample was *T. fluviatilis*, hence giving some explanation of the displacement of Station 7 away from the remaining September stations.

October-January Grouping

The two most important species influencing ordination of stations from October to January were *Tabellaria fenestrata* and *Fragilaria crotonensis.* These species dominated the community through all the winter months, ordinating them into the second major grouping. Individual sampling months, however, were still grouped close together, as indicated by third component values. The secondary dominants responsible for this in October were *Tabellaria flocculosa, Chroococcus limneticus* and *Melosira italica.* Changes in secondary dominants in November to *Asterionella formosa* and *Stephanodiscus minutus* displaced these samples slightly from the previous month. A large increase of *T. fenestrata* and *S. minutus* in December and January, and *F. intermedia* and *M. islandica* in January ordinated these samples somewhat away from October and November. The overall community structure during this four month period, however, was not markedly different.

March-May Grouping

A distinct change in dominance from pennate to centric diatoms resulted in a shifting of ordinal station placement in the samples. *Stephanodiscus minutus* was the dominant species in March, ranging from 16 to 33% density at the eight stations. *Melosira islandica, M. italica*, and *Stephanodiscus binderanus* were all present in high densities in March. April stations were characterized by a general decline of the four March dominants. Nine of the 29 species used in the ordination had average abundance levels above 5% during April, making the single most abundant species less important as an ordinating factor. The general trend for

May was a community more similar to winter months, with *Tabellaria fenestrata* and *Fragilaria crotonensis* increasing in density. The most important species in May, however, was *Melosira islandica*, which dominated the community. The combination of these dominant taxa influenced ordinal placement of the May stations between the winter and remaining spring months. The high density of *Stephanodiscus* at station 1 along with relative low abundance of *M. islandica* ordinated this station apart from the remaining May stations.

Discussion

The close proximity of sample stations in the study area explains the general lack of spatial variability observed. The Kintzele Ditch and Dunes transects are only 700 m apart. Although the Michigan City transect is somewhat separated from the other two, it is only about 4600 m northeast of the Dunes transect. The Michigan City Harbor area, including the influences of Trail Creek, the Northern Indiana Public Service Company generating station, and the high volume of boating and recreational activity, did not appear to greatly influence ordination of the phytoplankton communities considered in the study area. Spatial variability is usually only shown over a large expanse of the lake, or where significant environmental factors such as major rivers or point source wastewater inputs exist (15). This did not appear to be the case in this study. The occasional ordinal displacement of a single sample away from the remaining samples within a month was not consistent throughout the study. Sampling bias (5,8) or the plankton patchiness common in all aquatic systems (25) could explain some of these variations.

Although statistical significance could be found among individual stations for given populations in certain months, the general overview delineated by the principal components analysis revealed general community stability in the three major seasonal groupings. The year-long sampling regimen provided a good portrait of the temporal succession of species dominance. Minor changes occurred in principal component groups from June through September, from October through January, and March through May. Major shifts from one relatively stable period to the next occurred as the result of temporal shifts in species and abundance. The changeover of species dominance appears to be cyclic, but gaps appearing in the ordination may not have been as pronounced if sampling had been more frequent. This seasonal succession in Lake Michigan has been shown by several other investigators (6, 19, 20).

Principal components ordination analysis allowed graphic evaluation of relationships between samples, sites, and dates. Since the analysis was restricted to the numerically dominant taxa, it did not include all of the species collected. It did, however, express community similarities for an objective overview of the changes in phytoplankton community structure over the year.

Literature Cited

1. BRAY, J. R., and J. T. CURTIS. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Mono. 27: 325-349.
2. BRIGGS, S. A. 1872. The diatomaceae of Lake Michigan. The Lens 1: 41-44.
3. DROUET, F., and W. DAILY. 1973. Revision of the coccid Myxophyceae. Hafner Press, New York. 222 p.
4. GAUCH, H. G. Jr., and R. H. WHITTAKER. 1972. Comparison of ordination techniques. Ecol. 53: 868-875.
5. GILBERT, J. Y., 1942. The errors of the Sedgewick Rafter Counting Chamber in the enumeration of phytoplankton. Trans. Amer. Micro. Soc. 61: 217-226.

6. HOLLAND, R. E. 1969. Seasonal fluctuation of Lake Michigan diatoms. Limnol. and Oceanogr. 14(3): 423-436.
7. LAUER, T. E. 1975. Phytoplankton associations in Indiana near-shore areas of the southern basin of Lake Michigan in 1973-1974. M.S. Thesis. Ball State University, Muncie, IN. 152 pp.
8. MCALICE, B. J., 1971. Phytoplankton sampling with the Sedgewick Rafter cell. Limnol. and Oceanogr. 16(1): 19-28.
9. MCCOMISH, T. S. 1975. Interspecies relationships of fish in Indiana waters of Lake Michigan, Final Report, Fed. Aid Proj. 3-150-R, Ball State Univ. 125 pp.
10. ORLOCI, L. 1966. Geometric models in ecology. l. The theory and application of some ordination methods. J. Ecol. 54: 193-215.
11. PATRICK, R., and C. W. REIMER. 1967. The diatoms of the United States. Vol. 1. Fragilariaceae, Eunotiaceae, Naviculaceae. Mono. 13, Phila. Acad. of Nat. Sc. 688 pp.
12. PIELOU, E. C. 1966. The measurement of diversity in different types of biological collections. J. Theor. Biol. 13: 137-144.
13. PRESCOTT, G. W. 1951. Algae of the western Great Lakes area. Cranbrook Inst. Science Bull. 31. 946 pp.
14. ROCKWELL, D. C., D. S. DEVAULT III, M.F. PALMER, C.V. MARION, and R. J. BOWDEN. 1980. Lake Michigan intensive survey 1976-1977. EPA-905/4-80-003A. 155 pp.
15. SCHELSKE, C. L., L. E. FELDT, and M. S. SIMMONS, 1980. Phytoplankton and physical-chemical conditions in selected rivers and the coastal zone of Lake Michigan, 1972. Univ. of Mich. Great Lakes Res. Div. Pub. No. 19. 162 pp.
16. SMITH, G. M. 1950. The freshwater algae of the United States. McGraw Hill, Inc., New York. 719 pp.
17. STOERMER, E. F. 1967. A historical comparison of offshore phytoplankton populations in Lake Michigan. *In* Studies on the environment and eutrophication of Lake Michigan. J.C. Ayers and D. C. Chandler. Great Lakes Res. Div. Spec. Rep. No. 30, pp. 47-77.
18. STOERMER, E. F., and E. KOPCZYNSKA. 1967. Phytoplankton populations in the extreme southern basin of Lake Michigan. 1962-1963. Great Lakes Res. Div. The Univ. of Michigan. Proc. 10th Conf. Great Lakes Res. 1967.
19. STOERMER, E. F., and J. J. YANG. 1969 Plankton diatom assemblages in Lake Michigan. Univ. of Mich. Great Lakes Res. Div. Spec. Rep. 47. 268 pp.
20. ________. 1970. Distribution and relative abundance of dominant plankton diatoms in Lake Michigan. Univ. of Mich. Great Lakes Res. Div. Spec. Rep. No. 16. 64 pp.
21. SWAN, J. M., R. L. DIX, and C. F. WEHRHAM. 1969 An ordination technique based on the best possible stand-defined axis and it's application to vegetative analysis. Ecol. 50: 206-212.
22. TIFFANY, L. H., and M. E. BRITTON. 1971. The algae of Illinois. Hafner Pub. Co. New York. 407 pp.
23. WEBER, C. I. 1970. Methods of collection and analysis of plankton and periphyton in the water pollution surveillance system. U.S. Dept. Interior Pub. 27 pp.
24. ______. 1971. A guide to the common diatoms at water pollution surveillance system stations. U.S. Gov. Printing Office. 101 pp.
25. WIEBE, P. H., and W. R. HOLLAND. 1968. Plankton patchiness: Effects on repeated new tows. Limnol. and Oceanogr. 13(2): 315-321.