DIATOM DEATH ASSEMBLAGES IN RECENT LAKE GEORGE SEDIMENTS

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ABSTRACT

Diatom death assemblages from recent sediments in Lake George, New York, are sensitive indicators of environmental quality. Quantitative analysis of diatom frequency data from 100 surface-sediment samples permits recognition of several diatom biotopes that represent differing responses to nutrient enrichment and water depth. Biotopes representative of varying levels of nutrient enrichment coincide with human population density pattern around the lake.

INTRODUCTION

The use of diatom death assemblages from lake sediments as a means of determining water quality has a relatively long history (Nipkow, 1927; Wurthrich, 1961; Stockner and Benson, 1967; Stockner, 1971). The diatom community is very sensitive to environmental factors (see paper by Siegfried in this volume), and assemblages of diatom frustules in bottom sediments provide a time-averaged record of these community responses. By using a large number of sediment samples taken from all regions of the lake and by using multivariate techniques to analyze the data, we felt that we could provide reconnaissance-level information on the environments of Lake George.

This paper is based on a thesis by Bloomfield submitted in 1972. The study was part of a larger project designed to obtain base-line information on the limnology of Lake George, establishing the lake as a site in the International Biological Program. The primary objective of the study was to determine the environmental heterogeneity of Lake George and to determine whether or not there is a eutrophication gradient reflecting the pattern of residential and commercial development around the south end of the lake.

METHODS

One hundred twenty-five sediment samples were taken with an Ekman dredge between June 28 and July 1, 1969, on a grid consisting of stations ½ mile (0.8 km) apart perpendicular to the north-south axis of the lake and 1 mile (1.7 km) apart parallel to the axis. The grid was initialized with a randomly chosen point just south of Dome Island. Twenty-five additional samples were taken between October 29, 1969 and August 25, 1971, in conjunction with other studies.

The flocculent layer was carefully removed from each dredge sample and a 1-gram portion (wet weight) was used; based on observed and inferred sedimentation rates for Lake George, the layer sampled probably represented 3 to 10 years of accumulation. The material was digested by nitric acid and potassium dichromate following standard procedures. The strews were mounted with Hyrax mounting medium.

Each slide was examined under a light microscope by integral scans at 1000 power until at least 400 valves were counted. Whole frustules were counted as 2 valves. Diatoms were identified to genus for 110 samples and to species for 40 selected samples using as references Hustedt (1930), Smith (1938), Stoermer and Yang (1969), and Patrick and Reimer (1966). Assistance in indentifying a few difficult specimens was provided by Dr. Ryan Drum. A paired t-test indicated that the counting method was not biased at the 95% level.

RESULTS

Twenty-nine genera and over sixty species of diatoms were identified from the flocculent layer of the sediments (Table 1). The samples were dominated by 13 genera, all of which were also common in plankton and periphyton samples analyzed in collaborative studies.

The composition of many of the samples is typical of a deep, oligotrophic lake with a high percentage of *Cyclotella comta*, *Cyclotella operculata*, and *Tabellaria fenestrata*. However, in samples taken from near developed areas, mesotrophic-eutrophic indicator species such as *Fragilaria crotonensis*, *Synedra acus*, *S. ulna*, *Asterionella formosa*, and *Stephanodiscus astrae* are dominant. The few shallow-water samples show high proportions of epiphytic and benthic forms.

One hundred representative samples (Fig. 1) were analyzed using two complementary multivariate techniques. Cluster analysis (Sneath and Sokal, 1973) was used to group samples that have high coefficients of similarity into clusters and then group these in turn at successively lower levels as indicated by their decreasing similarity coefficients. In this way an objective, unambiguous hierarchical classification was obtained. Czekanowski's (1932) coefficient, also known as the generalized Sorensen coefficient, was used with unscaled percentage data. the results were expressed in the form of a dendrogram, with the samples represented by horizontal lines at the left of the diagram and the levels of clustering indicated by vertical lines of juncture (Fig. 2). Fifteen clusters of samples (biotopes) were defined, all clustering above the 65%

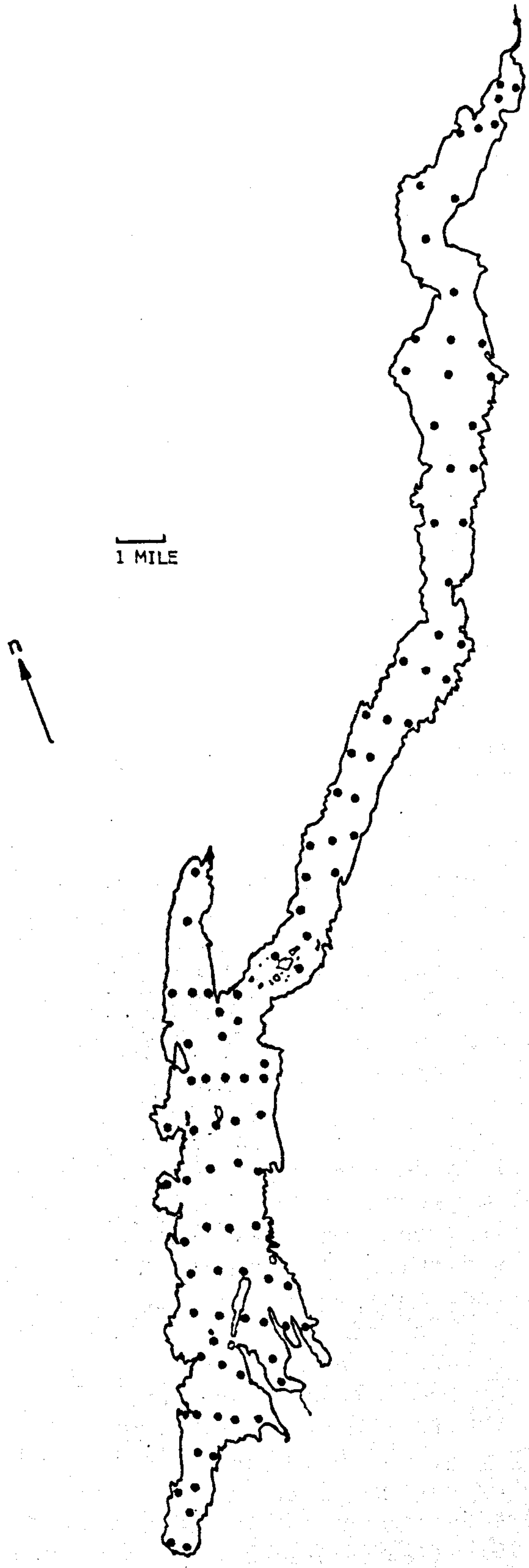

Figure 1. Locations of sampling stations, Lake George, New York.

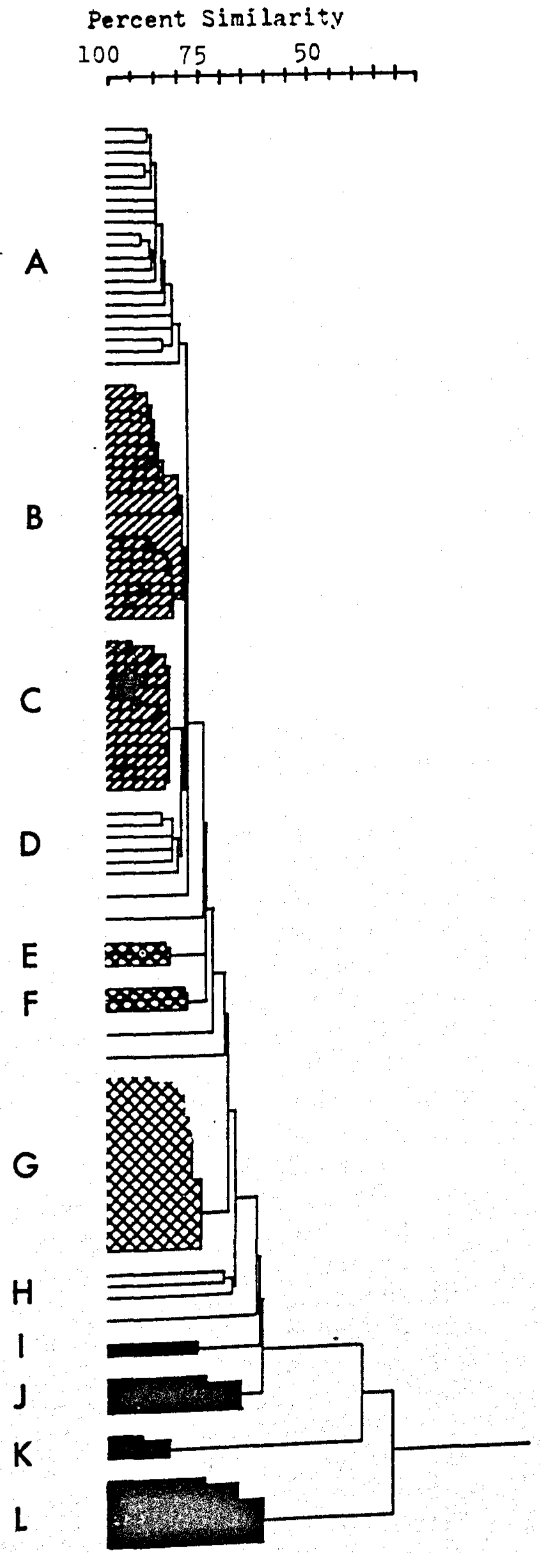

Figure 2. Cluster dendrogram showing diatom biotopes.

Table 1

Diatoms identified in Lake George sediments

Melosira granulata	Opephora martyi
M. islandica	Stephanodiscus astrae
M. crenulata	S. niagarae
M. italica	Cyclotella comta
Diatoma vulgare	C. operculata
D. anceps	C. bodanica
Fragilaria crotonensis	C. stelligera
F. brevistrata	C. kutzinghiana
F. capucina	C. glomerata
F. construens	C. meneghiniana
F. pinnata	Synedra acus
Tabellaria fenestrata	S. ulna
T. flocculosa	S. tenera
Navicula spp.	Asterionella formosa
Cymbella lanceolata	Pinnularia gibba
C. cistula	Achnanthes lanceolata
C. tumida	A. minutissima
Diploneis elliptica	A. exigua
Nitzschia palea	Cocconeis pediculus
N. paradoxa	C. placentula
Surirella ovalis	Stauroneis phoenicenteron
S. ovata	Cymatopleura solea
Gyrosigma acuminatum	Gomphonema acuminatum
Amphora ovalis	G. olivaceum
Frustulia rhomboides	Amphipleura pellucida
Eunotia major	Meridion circulare
E. arcus	Epithemia sorex
E. pectinalis	E. zebra
Neidium dubium	Caloneis bacillum

level of similarity; several unique samples did not cluster at a significant level.

Polar coordinate ordination (Bray and Curtis, 1957; Park, 1968; Park, 1974), in conjunction with an iterative technique (Goff and Zedler, 1968), was used to portray gradational relationships among the samples. Dissimilar samples served as endpoints for axes in a multidimensional model, with the other samples arrayed on the basis of their proportional dissimilarities to the endpoint samples. The proximity of any two samples is a measure of their similarity. The two-dimensional model accounts for 66% of the dissimilarity among the samples in this study.

Ordination was particularly useful in determining environmental and biotic trends. Water depth shows a general increase from right to left in the model (Fig. 3a). This trend was more accurately determined, as shown by the arrow, by fitting a linear regression surface to the bathymetric data by a least squares method; the linear trend accounts for 33% of the variance. The relative percentage data for each genus were also plotted in the model. Asterionella formosa exhibits a trend that is very similar to the bathymetric trend (Fig. 3b). Cyclotella and Tabellaria trend toward the upper left and left respectively (Figs. 3c and 3d). Synedra, which is an indicator of eutrophic conditions, trends toward the bottom of the model (Fig. 4a). Navicula, Fragilaria, and Amphora ovalis trend toward the right side of the model, indicating shallow-water eutrophic conditions (Figs. 4b-4d). In summary, depth trends toward the left and a general pattern of nutrient enrichment for both depp and shallow stations trends toward the lower right; this nutrient enrichment trend is emphasized in Figure 5 by the density of shading of the biotopes plotted in the model.

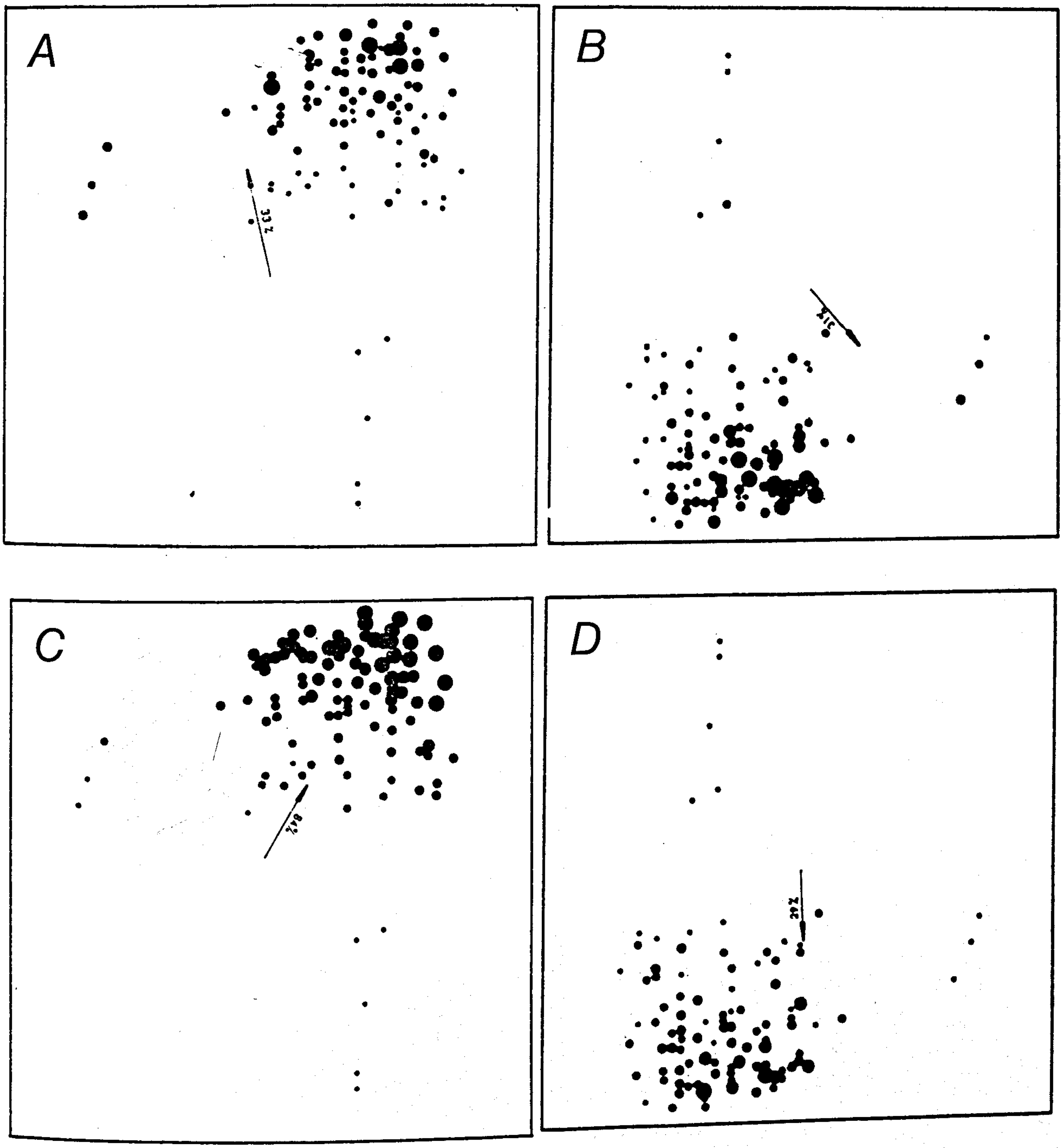

Figure 3. Ordination model. A- depth of water (diameter of circle is proportional to value for particular sample); B- <u>Asterionella formosa</u> (relative percentages, a = absent); C- <u>Cyclotella</u>; D- <u>Tabellaria</u>.

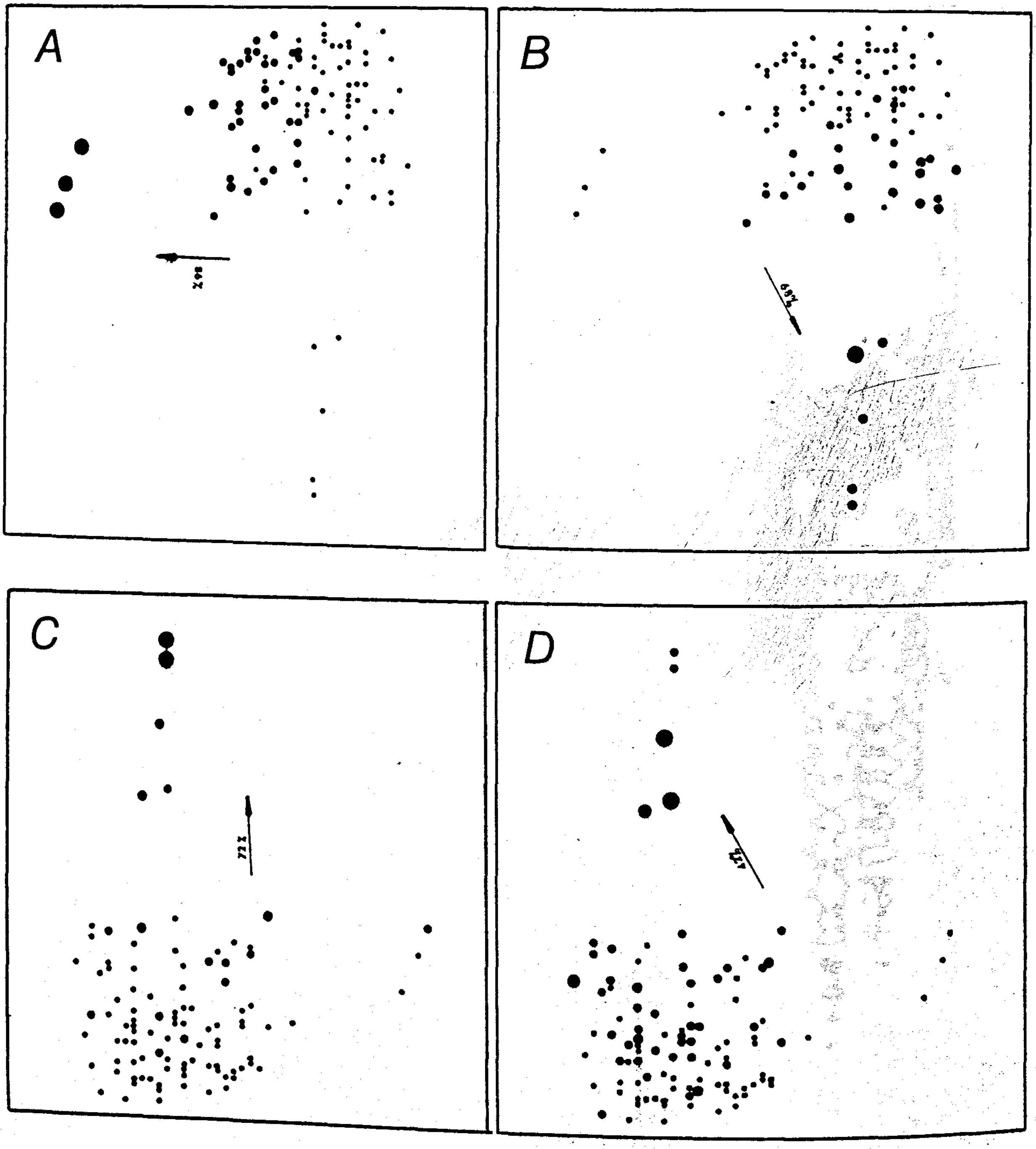

Figure 4. Ordination model continued. A- Synedra; B- Navicula; C- Fragilaria; D- Amphora ovalis.

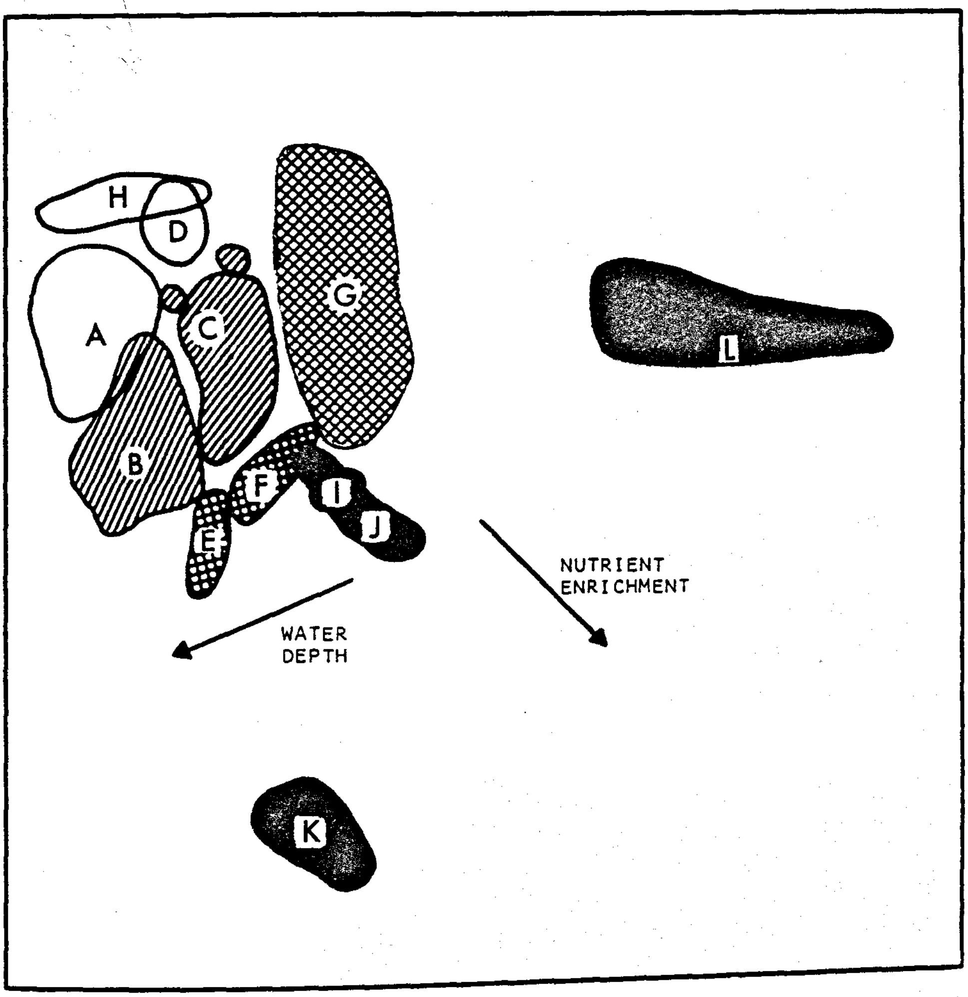

Figure 5. Biotopes plotted in ordination model; the darker the pattern the greater the inferred nutrient enrichment.

DISCUSSION

The distribution of nutrient enrichment in Lake George is shown in Figure 6, based on the patterns assigned to show the nutrient gradient in Figure 5. The relationship between trophic status, as inferred from the diatom assemblages, and the population centers around Lake George is quite striking. The diatom biotopes present compelling evidence that the eutrophication of Lake George is directly related to density of development.

The interpretations of the generic gradients and resulting diatom biotopes are based on the voluminous diatom literature and were made independent of any suspicions we had about trends of eutrophication at Lake George. However, the trends that are demonstrated have been confirmed by other studies, including several described in this volume.

Biotope L occurs in very shallow-water areas (<3 m) with abundant macrophytes. These are generally more productive than deeper areas.

Biotope K consists of three moderately deep stations. The flora is typically planktonic, with major components being Synedra ulna, S. acus, and Fragilaria crotonensis. Two of the stations are offshore from Lake George Village. When the samples were taken we noted that the sediments were anaerobic and that the hypolimnion contained almost no dissolved oxygen. A relatively high rate of algal productivity was also noted there (Stross, personal communication, 1971). The third station is near the mouth of The Narrows, an area with numerous campsites serviced by pit toilets at the time of this study.

Biotopes F, G, I, and J consist of samples from regions that are intermediate both in sources of nutrients and in water depth. For example, many of the samples in biotope G are from areas ranging in depth from 3 to 10 m, proximate to the smaller summer-residence villages such as Huletts Landing and Cleverdale. Macrophytes such as Potomogeton and the macroalga Nitella are quite common in these areas.

Biotopes B and C have typically planktonic floras, with the principal members being Asterionella formosa, Cyclotella comta, and Tabellaria fenestrata. These biotopes characterize the offshore areas of Lake George south of The Narrows. The admixture of oligotrophic and mesotrophic-eutrophic indicators suggest that these areas are beginning to feel the impact of cultural eutrophication.

Biotopes A, D, and H also have typically planktonic floras, dominated by Cyclotella. Biotope A is the most common biotope in the less developed northern basin. It is typical of deep-water areas (>25 m) that are still oligotrophic.

CONCLUSIONS

Using an easily executed sampling program and well established multivariate techniques, important environmental relationships were recognized for the whole of the Lake George basin. In particular:

- Lake George exhibits a considerable amount of biological heterogeneity which is related to the depth of water and the uneven residential and commercial development of the drainage basin; and
- Species indicative of eutrophic conditions are most common in the area near Lake George Village, the largest lakeside population center.

ACKNOWLEDGMENTS

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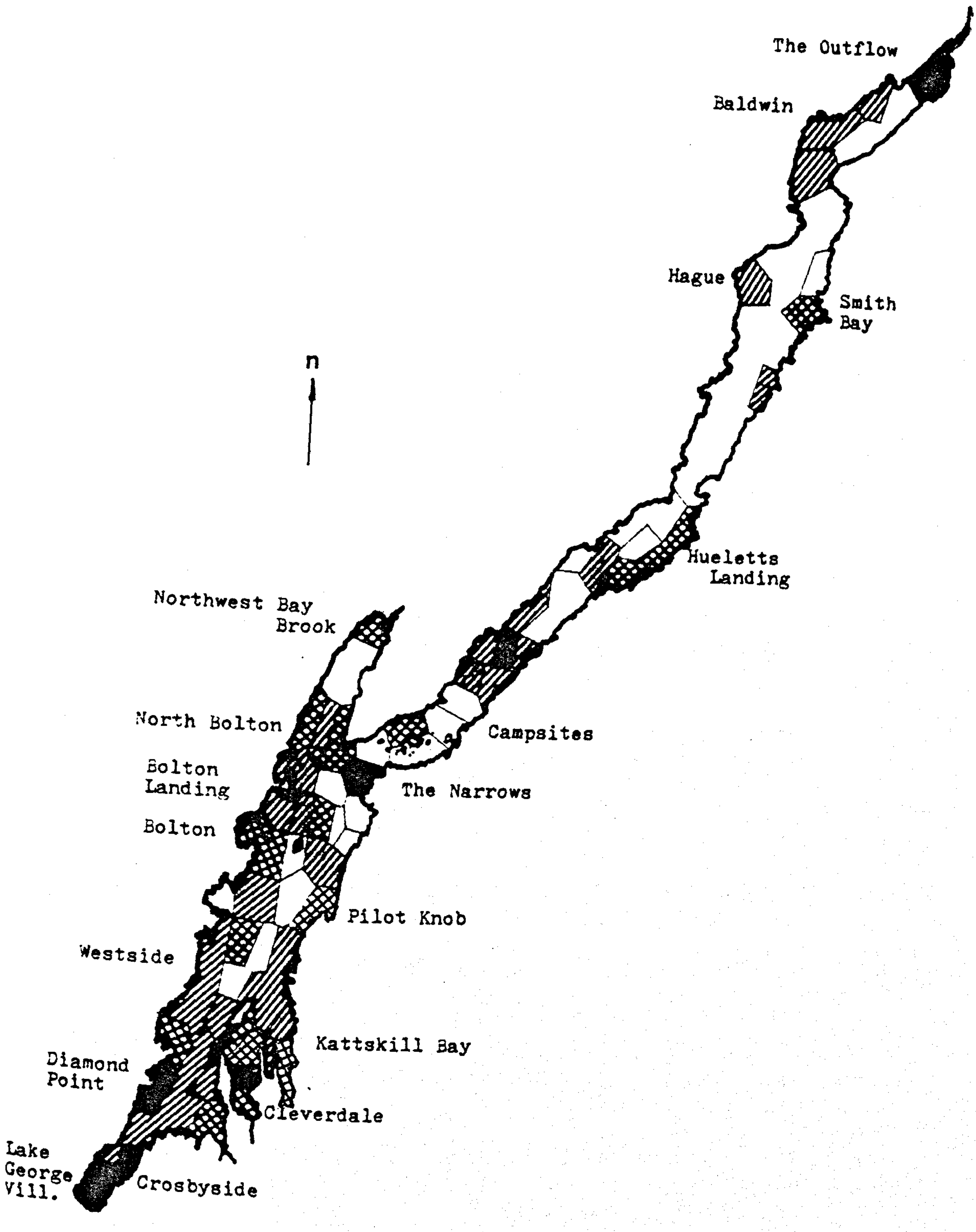

Figure 6. Distribution of diatom biotopes in Lake George; the darker the pattern the greater the inferred nutrient enrichment; note relationship to villages.

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