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Project Summary

Effects of Phosphorus Loading on Phytoplankton Distribution and Certain Aspects of Cytology in Saginaw Bay, Lake Huron

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Saginaw Bay has always been one of the more productive regions of the Great Lakes system. At the present time, it is also one of the most modified. Excessive nutrient and conservative element loadings are factors which have led to severe perturbation of primary producer communities in the region. Because of the physical dynamics of the bay region, idealized dilution gradients are grossly modified by transport of water masses and their entrained chemical constituents, fauna and flora into, as well as away from, the Bay. However, there appears to be considerable selection among population components of the assemblages transported. For example, blue-green algae appear to be conserved in the Bay while diatoms are subjected to great losses.

The major effort in this investigation was to provide data on phytoplankton biovolume that would support a model of processes occurring in Saginaw Bay. A method of estimating the actual viable fraction of the cell volumes of representatives of the various physiological groups of phytoplankton found in Saginaw Bay was developed, and polyphosphate body formation was studied. Results showed that substantial phytoplankton populations were exported from the Bay to Lake Huron. Under average wind conditions, most export occurred along the southern coast. These populations were then entrained in the general Lake Huron circulation and were spread down the Michigan coast southward from the Bay. Under certain advective conditions, however, phytoplankton were discharged from the Bay either to the north or directly offshore.

Cytological analysis showed that many species sequestered phosphorus in excess of their immediate physiological needs, in the form of polyphosphate bodies. Populations exported from the Bay also contained these polyphosphate bodies. Analysis of the polyphosphate bodies showed that significant quantities of certain toxic metals, notably lead, were incorporated into these inclusions.

Analysis of the relationship of total phytoplankton cell volume to protoplasmic constituent volume showed that crude cell volume measurements furnished a poor estimate of actual living biomass in many populations. It was concluded that more refined techniques are required to correctly convert estimates of cell number to estimates of biomass.

This Project Summary was developed by EPA's Environmental Research Laboratory, Duluth, MN, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Saginaw Bay has always been one of the more productive regions within the Great Lakes system. The productivity of

the fishery resource was undoubtedly one of the factors attracting early settlement in the area. Other natural resources of the drainage basin provided the incentive for early settlement and substantial economic growth in the region. The timber resources of the Saginaw River and its tributaries were rich and easily accessible, which led to early development of the area and the establishment of an industrial base. Once cleared of its natural vegetation, much of the land was found suitable for intensive agricultural practices. Finally, the presence of subsurface resources, primarily petroleum and salt, made possible the establishment of one of the midwest's centers of chemical industry. Unfortunately, the development of the Saginaw-Bay City-Midland industrial complex and intensive regional agriculture proceeded at the expense of deterioration of water quality within Saginaw Bay. At the present time it is one of the most seriously modified parts of the Great Lakes system. During the past few decades Saginaw Bay has been beset with water quality problems including obnoxious algal blooms, taste and odor problems in municipal water supplies, and fish flesh tainting. It should be pointed out that the perturbation of primary producer communities in this region reflects the effects of many factors. The most obvious of these are the effects of excessive nutrient loadings. At the present time the waters of Saginaw Bay are probably the most productive in the entire Great Lakes system. The composition of the phytoplankton and benthic algal flora also reflects the effects of extreme conservative element loadings. Although these loadings have apparently been decreased to some degree in recent years, the flora of the Bay still contains many elements usually found in brackish water localities. Finally, although not experimentally documented, certain population distributions within the Bay can most plausibly be explained by direct toxic effects.

Saginaw Bay is also an extremely dynamic system. There are strong gradients in almost all factors of physiological interest between the lower Bay and the open waters of Lake Huron. As might be expected, these gradients are reflected in the population and community responses of the phytoplankton flora. Idealized dilution gradients are grossly modified by mass transport of water masses and their entrained chemical constituents, fauna, and flora into, and away from, the Bay. There appears to be considerable selection among the population components of the assemblage(s) being transported. Certain populations, primarily blue-green algae, appear to be conserved, in the sense that their abundance is highly correlated with the concentration of biologically conservative chemical elements being discharged from the Bay. Other populations, primarily diatoms, are apparently subjected to much greater losses during transport. At the same time, water masses from Lake Huron, containing biological communities adapted to physical and chemical conditions found in the open lake, are imported into the Bay. The purpose of this large scale investigation was to provide data on phytoplankton biovolume which would support a model of processes occurring in the Bay. Biovolumes were estimated and polyphosphate bodies were examined in many species.

Parts of this investigation were previously reported, namely: studies of primary consumer organisms in Saginaw Bay and southern Lake Huron (Gannon, in prep; Stemberger et al. 1979), studies of physical and chemical conditions in Saginaw Bay (Smith et al. 1977), a study of phytoplankton abundance and distribution in southern Lake Huron (Stoermer and Kreis, et al. 1980) a process oriented model of Saginaw Bay (Biermann, et al. 1980). Although each of these studies was the responsibility of a different laboratory, common sampling techniques were used. Pertinent data are reproduced in this report, detailed methods are given only for bivolume calculations and polyphosphate body studies.

In most instances phytoplankton samples were taken by submersible pump and fixed immediately with 4% gluteraldehyde. Samples were kept on ice in the dark until they were processed into slides by the membrane clearing technique. Sampling cruises were conducted at approximately monthly intervals over a 2-year period.

Population estimates were developed from 1 mm strip counts of randomly selected areas of the slide preparations. Populations were enumerated and dimensions of the taxa recorded. The volume data were converted to an estimate of carbon biomass. Volume density estimates of cell components (cell wall, chloroplasts, vacuoles, storage products, and remaining cytoplasmic material) were obtained by electron microscope morphometric methods. Estimates of volume density were determined using both paper profile cut-and-weigh and grid-point-counting techniques.

Eight taxa were selected for quantitative stereological analysis, including representatives from the classes Cyanophyceae, Bacillariophyceae, Euglenophyceae, Cryptophyceae, Dinophyceae, and Prymnesiophyceae. Seventy-five micrographs were examined for each taxon, except where scarcity of a particular taxon in the water samples necessitated a somewhat reduced sample size. In all cases, examination of coefficients of variation and plots of cumulative means and variances indicated adequate sampling of the material. A transparent 0.5-cm square sampling lattice was superimposed over the micrographs for quantitative measurements.

Cell volume estimates were obtained from light microscopic examination of cells from the same assemblages used for quantitative stereological analysis.

Both x-ray energy dispersive analysis (to confirm the presence of phosphorus) and light microscopy were used in the examination of polyphosphate bodies.

The results of the study reported here indicate that the problems associated with biovolume estimates can be both understood and, in many cases, minimized. The inherent cellular organization of some species contributes significantly to the error of biomass calculations currently in use. Corrected cellular volumes determined from the morphometric data by subtracting the volume of inert structures from the total volumes were found in this study. Table 1 indicates the striking differences found in various taxa.

Table 1. *Percent of Total Cellular Volume Identified as "Metabolizing Biovolume" for Selected Taxa*

A. flos-aquae	*64.1*
S. binderanus	*29.9*
F. capucina	*43.5*
E. viridis	*44.6*
C. erosa	*67.7*
P. lindemann:	*58.6*
Haptophyte sp. #1	*58.3*
Haptophyte sp. #2	*81.9*

Polyphosphate inclusion bodies were widely found in diatoms and even in algae in Saginaw Bay. The abundance of these bodies corresponds to the usual pattern of greatest total phytoplankton density, and to the most probable area of excursion of materials from the Bay.

Conclusions and Recommendations

1. The use of electron microscopic morphometric analysis leads to a more accurate estimate of biovolume than other methods presently in use.
2. The ecological causes and consequences of polyphosphate storage in phytoplankton may be important

in evaluating impact of areas such as Saginaw Bay on the rest of the Great Lakes system.

3. It was previously assumed that polyphosphate body formation was important only in prokaryotic organisms. The results of this study suggest that the mechanism is present in most of the major physiological groups present in the Great Lakes. Notable exceptions were the Cryptomonads and Dinoflagellates. Although induction was not attempted in species of these groups under experimental conditions, none of the wild populations examined contained polyphosphate bodies. Representatives of all of the other major algal physiological groups did. Most of the species examined in the study are usually associated with eutrophied conditions in the Great Lakes and it is possible that luxury consumption of phosphorus is one of the factors which confers competitive advantage on these populations. Further research will be needed to answer this question.
4. These results indicate that heavy metals may be sequestered in polyphosphate bodies.
5. Meteorological conditions have a strong influence on the eventual fate of materials entering the Bay, and on the fate of phytoplankton populations generated in the Bay. Further research should be devoted to the effects of conditions which force strong advective events on processes in Lake Huron.

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The complete report, entitled "Effects of Phosphorus Loading on Phytoplankton Distribution and Certain Aspects of Cytology in Saginaw Bay, Lake Huron," (Order No. PB 83-250 035; Cost: $14.50, subject to change) will be available only from:

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