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Laurentian Great Lakes Monitoring: Biology and the Lake Erie Case

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Management Perspective

Great Lakes 2000, Lake Erie LaMP, phosphorus management policy, fisheries

Environment Canada, U.S. EPA and State and Provincial governments conduct research and monitoring in the Great Lakes. Biological monitoring tends to be less emphasised than chemical monitoring. New approaches developed at NWRI provide a way to assess the biological benthic community and recommend goals for improvement. Lake Erie's response to GLWQA nutrient load controls and zebra mussels was assessed with data between 1968 and 1997. Nutrient load reductions caused a reduction by about 50% in chlorophyll (algae) in the central and east basins before mussels arrived. Larger changes occurred in the west basin. A previous relationship between algae population and photosynthesis was used to predict that lake production fell, in the central and east areas, 35%-46% due to lower nutrients and a further 12%-15% due to mussels. Phosphorus decreased in the central and east basins after Zebra mussels but most of the loss has been recovered in 1996 and 1997.

Present paper February 17-18 in Finland, proceedings published later.

Abstract

The Laurentian Great Lakes began to suffer the effects of European settlement in the 1800s. The initial effects were from erosion due to land clearing and draining and agriculture. The growth of sizeable communities began to add pollution effects and by the 1920, there was concern for both pollution and overfishing. The growing North American economy, the invention of chlorinated chemicals, agricultural use of artificial fertilizers, the innovation and use of detergents, and the connection of the population to the lakes via growing but inadequate sewage systems all contributed to increasing effects on the Lakes. Pollution increased until the late 1960s. At that time the public was shocked by a series of studies that showed that even these huge lakes could be seriously polluted by the population on the shores. Eutrophication symptoms were similar to those elsewhere: beach closings, objectionable algal accumulations, fish kills, and severe oxygen depletion in Lake Erie. Eventually, the Great Lakes Water Quality Agreement between Canada and the U.S. was signed in 1972. The agreement mandated eutophication controls and monitoring as well as research. Subsequent versions of the agreement concentrated on toxic chemicals and residual highly contaminated areas. Monitoring or long term research has been used to assess the lakes and the effects of controls as well as to increase our understanding of the systems so that management decisions can be made on the basis of good information.

Surveillance des Grands Lacs laurentiens : aspects biologiques et cas du lac Érié

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Sommaire à l'intention de la direction

Grands Lacs 2000, Plan d'aménagement panlacustre du lac Érié, politique de gestion du phosphore, pêches

Environnement Canada, l'EPA et les gouvernements des États et des provinces effectuent des activités de recherche et de surveillance dans les Grands Lacs. On a tendance à mettre l'accent sur la surveillance chimique, plutôt que sur la surveillance biologique. Grâce à de nouvelles approches élaborées à l'INRE, on dispose de nouvelles méthodes pour l'évaluation biologique de la communauté benthique, ainsi que d'objectifs d'amélioration recommandés. À l'aide des données obtenues, on a évalué, de 1968 à 1997, la réponse du lac Érié aux mesures de limitations des charges de nutriments et de lutte contre les moules zébrées prévues par l'Accord de 1972 relatif à la qualité de l'eau dans les Grands Lacs. Les réductions des charges de nutriments ont entraîné une réduction d'environ 50 % de la chlorophylle (algues) dans les bassins du centre et de l'est, avant l'arrivée des moules. On a noté des changements plus importants dans le bassin ouest. On a utilisé un rapport prévisionnel développé antérieurement, qui établit un lien entre la population d'algues et la photosynthèse, pour évaluer, dans les zones du centre et de l'est, la chute de production du lac à 35 - 46 % à cause des teneurs plus faibles en nutriments, et à une valeur supplémentaire de 12 - 15 % à cause des moules. On a observé une diminution du phosphore dans les bassins du centre et de l'est après l'arrivée des moules zébrées, avec un rétablissement compensant la plus grande partie de cette baisse en 1996 et en1997.

Présentation de l'article le 17 ou le 18 février en Finlande; les actes seront publiés ultérieurement.

Résumé

Au cours du XIX^e siècle, les Grands Lacs laurentiens ont commencé à souffrir des effets de la colonisation par les Européens. Le premier de ces effets était l'érosion due au déboisement, au drainage et à l'agriculture. On a observé des effets de pollution dus à la croissance de grandes communautés et, dès les années 1920, on était préoccupé par la pollution et la surpêche. Divers facteurs ont contribué à accroître ces effets nocifs sur les lacs, notamment la croissance de l'économie nord-américaine, l'invention des produits chimiques chlorés, l'utilisation agricole de fertilisants artificiels, la découverte et l'utilisation des détergents, ainsi que l'établissement de liens entre la population et les lacs à cause de la croissance de réseaux d'égouts inadéquats. La pollution a augmenté jusqu'à la fin des années 1960. À cette époque, le public fut choqué par une série d'études montrant que même ces immenses lacs pouvaient être gravement pollués par la population riveraine. Les symptômes d'eutrophisation étaient semblables à ceux qu'on note ailleurs : fermetures de plages, accumulations d'algues créant des problèmes, mortalités de poissons et fortes carences en oxygène dans le lac Érié. Cette situation a entraîné la signature de l'Accord relatif à la qualité de l'eau des Grands Lacs par le Canada et les États-Unis en 1972, qui prévoyait des mesures de surveillance et de limitation de l'eutrophisation, ainsi que des programmes de recherche. Par la suite, on a modifié l'Accord pour afin de mettre l'accent sur la limitation des substances chimiques toxiques et sur les zones fortement contaminées par des substances résiduaires. On a utilisé des programmes de surveillance ou de recherche à long terme pour évaluer la condition des lacs et les effets des mesures de limitation et pour mieux connaître ces réseaux, afin d'être en mesure de prendre des décisions de gestion mieux fondées.

Abstract

The Laurentian Great Lakes began to suffer the effects of European settlement in the 1800s. The initial effects were from erosion due to land clearing and draining and agriculture. The growth of sizeable communities began to add pollution effects and by the 1920, there was concern for both pollution and overfishing. The growing North American economy, the invention of chlorinated chemicals, agricultural use of artificial fertilizers, the innovation and use of detergents, and the connection of the population to the lakes via growing but inadequate sewage systems all contributed to increasing effects on the Lakes. Pollution increased until the late 1960s. At that time the public was shocked by a series of studies that showed that even these huge lakes could be seriously polluted by the population on the shores. Eutrophication symptoms were similar to those elsewhere: beach closings, objectionable algal accumulations, fish kills, and severe oxygen depletion in Lake Erie. Eventually, the Great Lakes Water Quality Agreement between Canada and the U.S. was signed in 1972. The agreement mandated eutophication controls and monitoring as well as research. Subsequent versions of the agreement concentrated on toxic chemicals and residual highly contaminated areas. Monitoring or long term research has been used to assess the lakes and the effects of controls as well as to increase our understanding of the systems so that management decisions can be made on the basis of good information.

Introduction

Monitoring in the Laurentian Great Lakes was begun in response to the Canada U.S Great Lakes Water Quality Agreement (GLWQA). This agreement which included the eight Great Lakes States and the Canadian Province of Ontario was signed in 1972. The purpose was to restore the chemical, physical, and biological integrity of the Great Lakes. Goals were established to lower phosphorus loading in Lakes Ontario and Erie by 50%. Subsequent versions of the agreement sought, in addition, to eliminate toxic quantities of toxic chemicals and to virtually eliminate persistent, bioaccumulating, organic chemicals.

The GLWQA has largely been a success. The trend towards increasing eutrophication in the most populated lakes Ontario and Erie was stopped and reversed. Now, total phosphorus concentrations of 10 ug/l of less are common in Lake Ontario and 20 ugP/l is common in west Lake Erie; these are about ½ of former concentrations. The occurrence of deformities and reproductive problems in aquatic birds decreased sharply since the use of DDT and the manufacture of PCBs were terminated as per scientific recommendations. Now there is much attention given to remedial action plans for the remaining highly polluted areas of concern. As well, there are planning processes underway to construct integrative lakewide management plans. Meanwhile, research continues to develop on the potential effects of increased UVB radiation, endocrine disrupting chemicals, and increasing numbers of exotic species. All of the recent activities involve public interaction as much as possible. A small sample of research and monitoring activities are highlighted below.

Monitoring and Research

In North America there are occasionally debates about whether research or monitoring is most required. The debates seem to correlate with the availability of funding. On one hand those in monitoring activities feel they should be comfortable there because monitoring itself implies continued activity and funding. On the other hand, research is sometimes seen as an approach to problem solving that can be switched on and off with the appearance of each problem. The nature of the Great Lakes Ecosystem is such that, while there can be great inertia, there is also a great deal of variability and real change can happen rapidly or take decades. Thus, research studies, to be valuable, must contain repeated sampling over several years. Research studies then begin to appear like monitoring and the distinctions between monitoring and research begin to disappear. Is research simply monitoring with a hypothesis to test? Is monitoring simply research that needs to be repeated for many years in order to achieve a meaningful result? Clearly, aquatic scientists need to practice their science in order to provide good advice to the public and to administrations. Indeed, some environmental problems related to human sewage and industrial effluents are permanent and must be managed scientifically rather than eliminated. Also, it is clear that both monitoring and research are closely allied scientific activities. Thus, they should be working in concert in ways that may have been inhibited by past organization behaviours. At present, funding restrictions and improved goal oriented behaviours no longer permit isolation between organizations operating in the Laurentian Great lakes. The present milieu is one of co-operation and communication towards common goals through bi-national processes and co-ordinated information gathering and dissemination.

Biological Monitoring

Biological monitoring in the Great Lakes is conducted by government laboratories and at some Universities. In general, monitoring concentrates on chemical contamination and eutrophication aspects and the biota are assumed to optimize their populations to their environment. One of the largest biological programs has been the long term (1981-95) "Bioindex" program of the Department of Fisheries and Oceans at the Canada Centre for Inland Waters in Burlington Ontario. The program sampled Lake Ontario phytoplankton, zooplankton, mysids, rotifers, ciliates, benthos, primary and secondary production and a suite of nutrients and physical factors (Johannsson et al. 1998). During previous surveys, the spatial variability was much less that the temporal variability. Therefore, two stations were chosen but they were sampled weekly. The work covers the period in which phosphorus concentration and load targets were achieved in the lake. Some of the many findings of the program were that primary production decreased 30% initially but did not respond to the last 4 ug/l of phosphorus reduction. Zooplankton production declined during the phosphorus reduction period. An example of the data is shown in Fig.1 which illustrates the changes in phytoplankton and zooplankton biomass on a seasonal average basis. Changes were more striking at certain times of the season. {BIOPHYTZPBW.PPT}

The Ontario Ministry of the Environment conducts monitoring for nutrients and phytoplankton in waters drawn from the nearshore in drinking water intakes. Benthic organisms are monitored nearshore as an indicator of overall ecosystem health. Summer, spring, and fall sampling is conducted for physical measurements including thermal and optical profiles and characterization of the lake bottom. The near shore monitoring is conducted in a different lake each year with emphasis on the lower lakes Erie and Ontario. Long term monitoring of contaminant levels in mussels, juvenile fish and selected sport fish is undertaken to track levels of persistent toxic contaminants. Sportfish results reflect the long-term spatially integrative effects of exposure to persistent bioaccumulative substances (eg: PCBs) and form the basis of a guide book that provides advice on safe consumption amounts.

A new approach is to develop a database on benthic species composition at unpolluted sites and construct a model to relate the populations to their environment. At polluted sites the benthic community is assessed in comparison to ideal populations in sites with similar physical properties but no pollution. Goals can then be established for rehabilitation of the affected population. This approach overcomes some of the problems of chemical monitoring and presents a way to monitor the desired result which is healthier and more complete biological communities (Reynoldson et al., 1995, 1997).

More and more the biota of the Great Lakes is changing due to exotic species introductions (Mills et al. 1993). The rate of introductions has increased in the last decades apparently due to trans Atlantic transport in ballast water of ships (Fig.2).(EXOTICS IN GRT LAKES BW.PPT) Zebra mussel, gobies, ruffe, and Bythotrephes sp. are notable introductions. Gobies and ruffe are still spreading and a new species was just discovered in November 1998. Thus, the biological composition of the lakes will be changing rapidly for some time to come as the ecosystem adapts to the new species. More research and monitoring is needed to understand how these exotic species are affecting the native species.

Process measurements such as primary production tend to be regarded as research subjects. Recently, the ability of Lake Erie to support fishing, given the present reduced phosphorus load and the mussel invasion, has been questioned. Charlton, (1998) used a long-term chlorophyll data set and relationships between primary production and chlorophyll to show that the majority of lake production decline was likely due to the nutrient controls and not the recent mussels in Lake Erie. Nevertheless, a consistent series of primary production measurements would be more reliable.

Water Quality Monitoring

Environment Canada and the United States Environment Protection Agency conduct monitoring and research on nutrients, chlorophyll, physical factors, toxic contaminants in water and sediment,. In addition, the eight U.S. states on the lakes and the Province of Ontario conduct monitoring for nearshore water quality and nutrients and contaminants loads in tributaries. The GLWQA contains a long list of substances that receive attention under the agreement. A particularly notable program by Environment Canada automatically samples the upstream and downstream areas of the Niagara River every three days. This program has shown changes in the export of phosphorus from Lake Erie that occurred with the invasion of zebra mussels. Most of the work, however, is done from specialized ships to enable good spatial coverage of the lakes whereas the frequency for monitoring may be one to three times per year; research studies may sample more often.

Chemical, physical, and biological research/monitoring in large lakes should be done as part of a system that includes tributary and some air monitoring. Sampling of lake sources is important because contaminants would likely be detectable in rivers and effluents long before they are detectable in open water or in biota. Thus, protection is enhanced if the sources themselves are monitored but there should be the safeguard of open lake monitoring and periodic biological assessments in case something is missed in the sources.

Finally, long-term aquatic science must take into account the physical variations caused by climate variations. The annual outflow from Lake Erie, for example, varies by ± 20% (Charlton, 1980). The flushing rate can affect the response of a lake to pollution. Moreover, in the case of Lake Erie, mini trends towards rising or falling water levels and outflow persist for 5 or more years so that conditions are not constant. In addition, for the last 25 years the water levels in Lake Erie have been unusually high. These climatic variations span a good deal of the duration of a Limnologist's career. Therefore it is critical to record and pay attention to long-term data that show the context in which any one study of some years fits.

The Lake Erie Case

As the deleterious effects of the excessive nutrient loading in Lake Erie became known the phosphorus from sewage plants became the main target for reduction. At the time detergents were formulated with phosphate builders that eventually accounted for about 20% of the phosphorus load. The GLWQA sought to eliminate the use of phosphates in detergents and this gave an early impetus to the lake cleanup effort. Eventually, construction of sewage plants and conversion to phosphorus removal caused further load reductions. The results of monitoring phosphorus load in Lake Erie are shown in Fig. 3. (TPLOADHISTORY ERIE.PPT) Reduction of the load to about 11,000 tonnes annually had the effect of reversing eutrophication back to loads of those in 1940. Now that the target loads have been reached there is difficulty in maintaining the tributary monitoring that would confirm that loads are being maintained. This may not be a time for complacency because the sewage plants are now old enough to need refurbishing and the funding arrangements that sponsored the original construction are no longer in place. The nutrient load reduction caused a decrease of about 3 ugP/l in the central basin of Lake Erie (Fig.4) (CBTP.PPT) during the summer months (Charlton et al. 1998). Perturbations in phosphorus concentrations in the mid-1990s coincided with the arrival and development of zebra mussel populations in the central basin. From a low concentration in 1995 phosphorus recovered in 1996 and 1997. The summer months seem ideal to monitor because the phosphorus values are most stable and free from bottom resuspension. Because the seasonal wind regime controls resuspension it is critical that the sampling effort be consistently spread over the year if annual means are desired in a long-term data set. There is a real loss of information when monitoring programs are reduced. Without high frequency and extensive sampling the probability of detecting a real change is decreased.

The Lake Erie situation as expressed in the GLWQA stressed recovery from anoxia in the central basin hypolimnion (Charlton, 1990). In recent years oxygen seemed to increase but in 1998 concentrations were near zero again as the thermocline took up a position close to the bottom. Continued research has shown that the oxygen situation is driven mainly by the physical characteristics of the lake and is very slow to respond (if at all) to phosphorus reductions. This case reinforces some of the most compelling needs for research and monitoring. When there has been management action it is desirable to find out whether the actions had the desired effect. This requires before and after data in large quantities if statistically valid conclusions are to be derived from the work. In times of little change the frequency of sampling may be reduced to a background level. At the moment, Lake Erie is changing rapidly.

Figure Captions:

Figure 1. Changes in phytoplankton and zooplankton populations during the "Bioindex" monitoring in the shallow east basin of Lake Ontario,

Figure 2. Cumulative introductions of animals and plants in the Great Lakes from data in Mills et al. (1993).

Figure 3. Total phosphorus load in all of Lake Erie 1968 to 1994.

Figure 4. Total phosphorus in the surface water of Lake Erie during summer 1968 to 1997.

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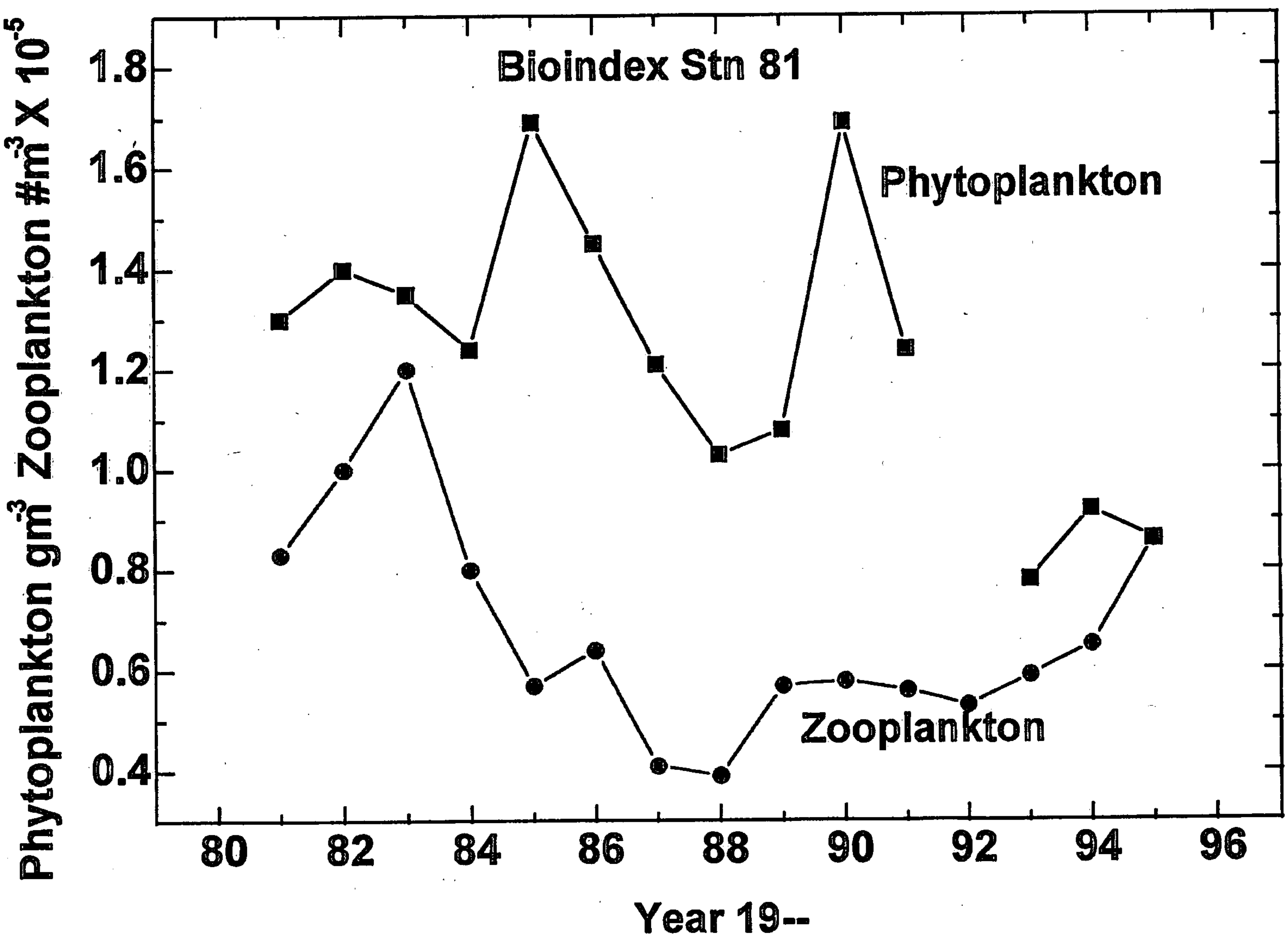
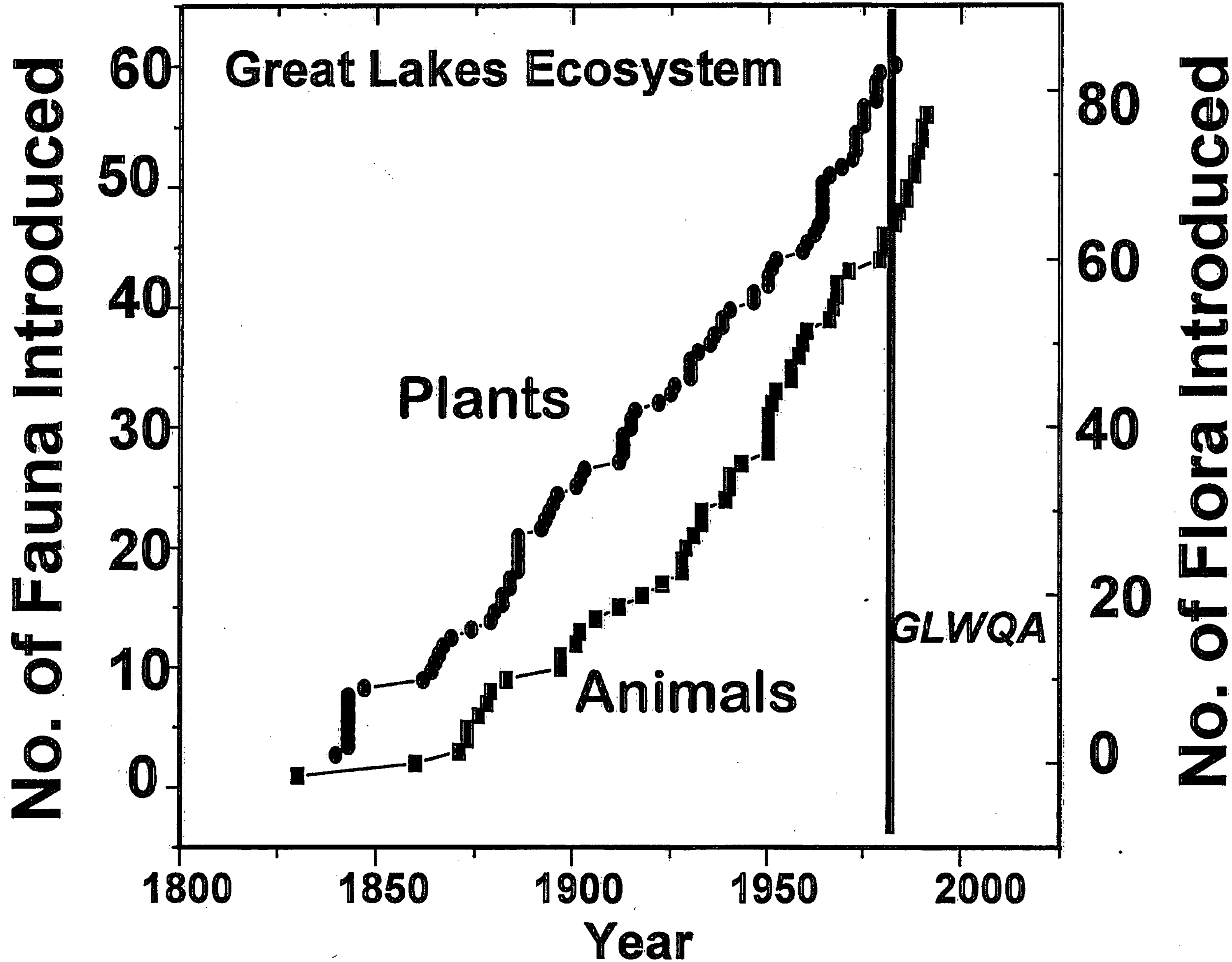
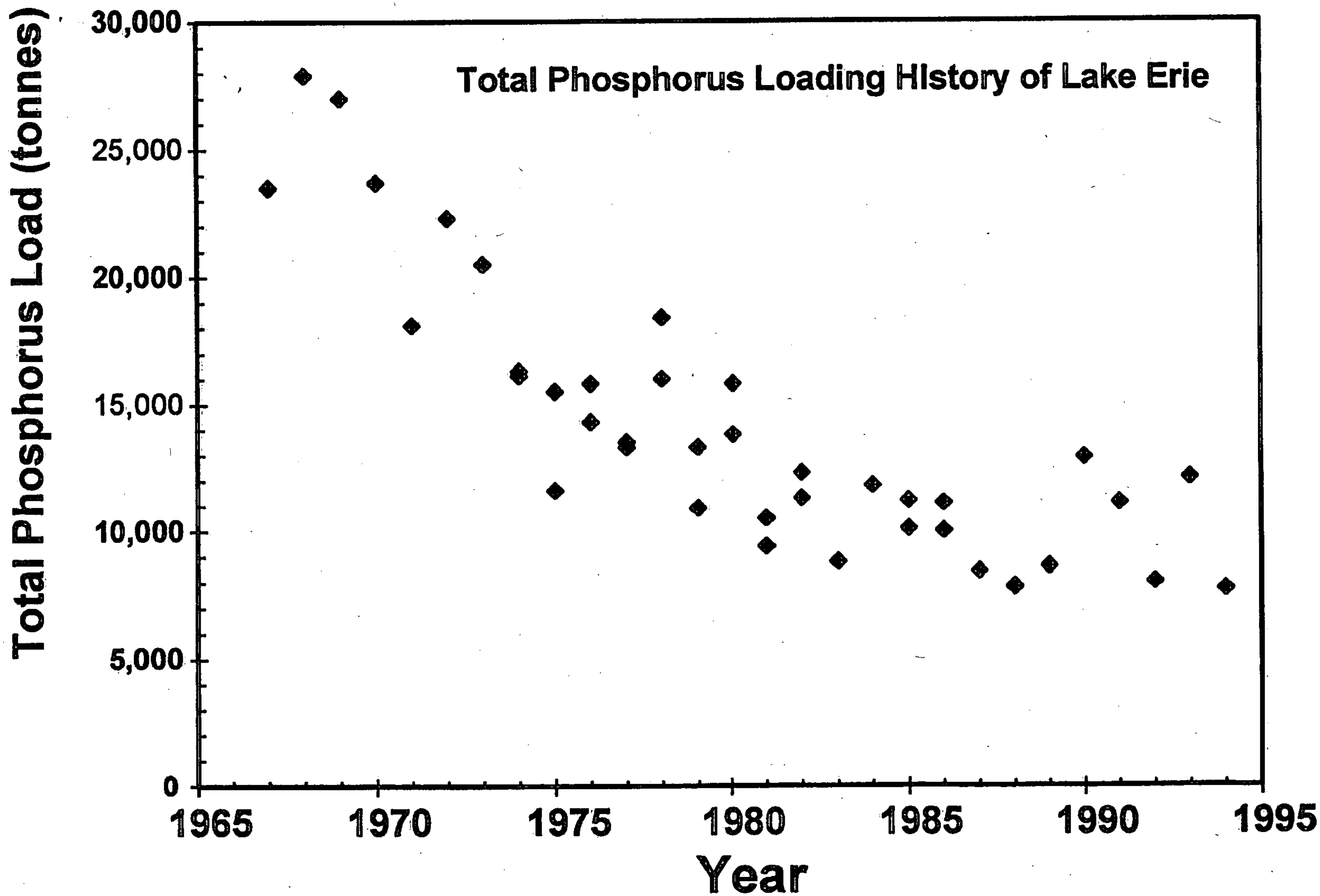
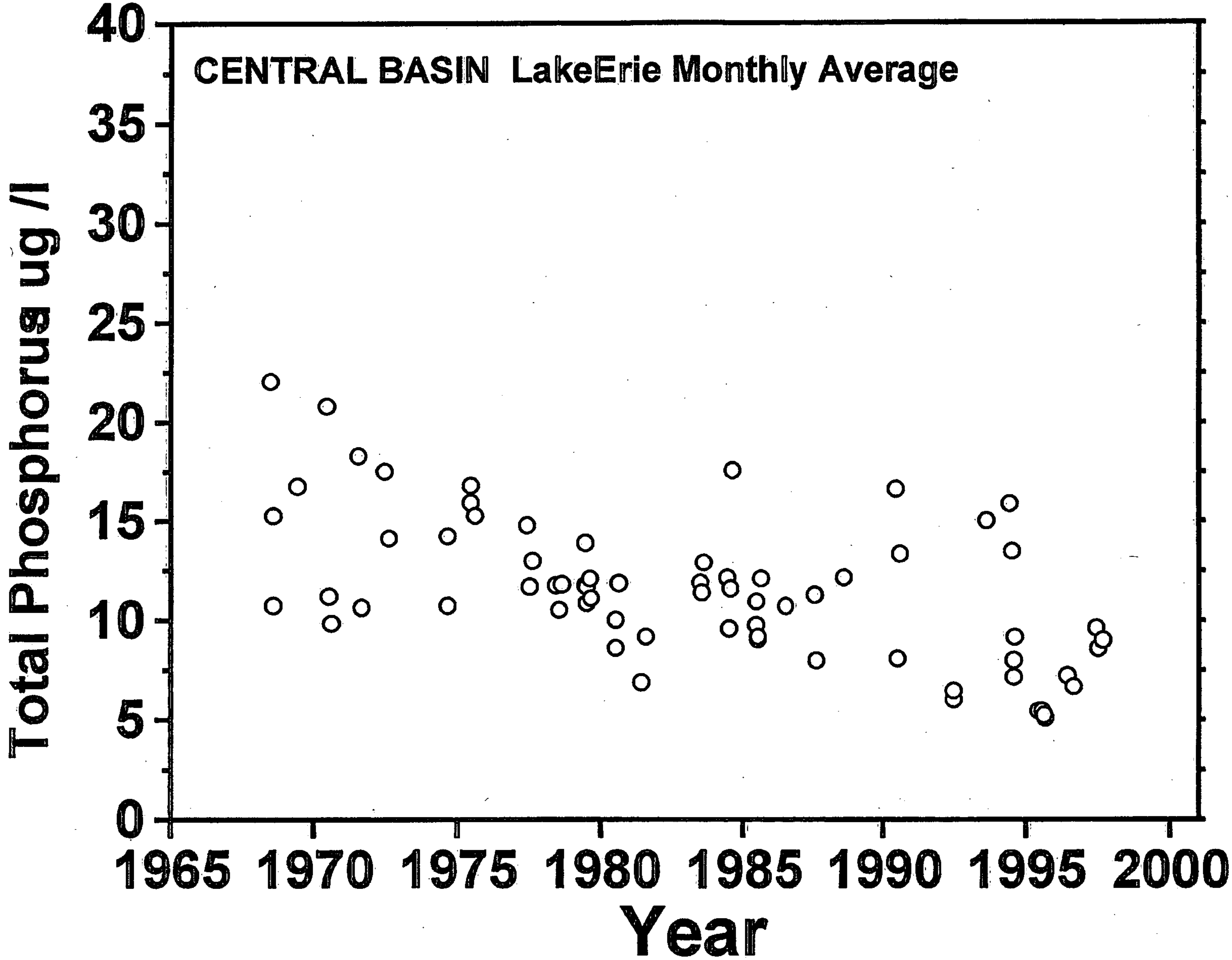

Bioindex Stn 81
Phytoplankton
Zooplankton
Phytoplankton gm^{-3} Zooplankton #m^{-3} X 10^{-5}
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
80
82
84
86
88
90
92
94
96
Year 19--



Great Lakes Ecosystem
Plants
Animals
GLWQA
No. of Fauna Introduced
No. of Flora Introduced
Year
0
10
20
30
40
50
60
0
20
40
60
80
1800
1850
1900
1950
2000


Total Phosphorus Loading HIstory of Lake Erie
Total Phosphorus Load (tonnes)
30,000
25,000
20,000
15,000
10,000
5,000
0
1965
1970
1975
1980
1985
1990
1995
Year


CENTRAL BASIN LakeErie Monthly Average
Total Phosphorus ug /l
Year
0
5
10
15
20
25
30
35
40
1965
1970
1975
1980
1985
1990
1995
2000

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