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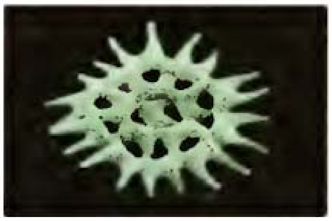

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Western Lake Erie Clean up: Phosphorus Control or Zebra Mussel Effect? - An Example of the Value of Long-term Data

BACKGROUND

Three decades ago, Lake Erie gained a reputation in the popular press as a "dead Lake". Because it was "first in line" to receive most of the phosphorus delivered to the lake from the major sources, Lake Erie's western basin typically experienced all of the classic symptoms of advanced eutrophy during the 1960's and early 1970's. In particular, the western basin suffered from pea-soupy algal blooms which rendered the water turbid and malodorous and interfered with recreational use and treatment for municipal drinking water supplies. This condition was the result of excessive production of phytoplankton in response to phosphorus loadings of 30-40 metric tons per day, originating in municipal sewage and agricultural drainage.

Significant progress towards rehabilitation of Lake Erie was initiated under the Great Lakes Water Quality Agreements of 1972 and 1978 (incl. amendments of 1983 and 1987), whereby target phosphorus loading reductions were set for both Canada and the United States. As a result, declines in phytoplankton biomass have been reported during the past two decades.

The arrival of the zebra mussel *(Dreissena polymorpha)* in the late 1980's increased the potential "improvement" of water quality owing to its filter feeding habit. Several investigators have reported dramatically improved water clarity and significant reductions in Lake Erie phytoplankton after the arrival of zebra mussels.

These two interventions, one planned (phosphorus loading control) and the other inadvertent (zebra mussel invasion) have had a combined impact on Lake Erie. When only relatively recent data (5-10 years) arc analyzed, there is a tendency to associate the present improved state of water quality of western Lake Erie (in regards to clarity, "greenness", level of algal interference with cater treatment, recreational use, etc.) solely with the arrival of zebra mussels. A much longer term data set is needed to place the water quality effects of the zebra mussel invasion in its proper perspective relative to the effects of phosphorus loading control.

The purpose of this "bulletin" is to illustrate the differences in interpretation of change that result when evaluations of a short-term (5-10 years) data record are contrasted with a longer-term data set. The data record consists of nearly 30 years of planktonic Chlorophyceae (green algae) density data (and two dominant chlorophyte genera, *Pediastrum* and *Scenedesmus)* measured in samples collected weekly from the Union Water System intake (north shore, western Lake Eric. at Kingsville, Ontario).

The Chlorophyceae were used in this analysis because representatives of this group have been abundant historically (second only to diatoms) and are likely more food web functional than the large colonial diatoms which have dominated western Lake Erie over the past several decades.

Planktonic chlorophytes are therefore very relevant to questions of "eutrophication reversal" and trophic interactions as potentially influenced by changes in phosphorus loading and establishment of filter feeding zebra mussels.

RESULTS AND DISCUSSION

During the mid-1980's, prior to the arrival of zebra mussels in western Lake Erie, the Chlorophyceae developed summer-fall maxima of 100-150 A.S.U. ml^{-1} separated by winter-spring lows of <20 A.S.U. ml^{-1} (Fig. 1). After the establishment *of* zebra mussels in late 1988, the summer peaks were either non-distinguishable (1990 and 1992) or greatly reduced in duration and magnitude (1989, 1991, 1993 and 1994). There is a clear inflection point in the cumulative sum of total chlorophyte density (Fig. 1) which coincides with the establishment of the mussel population.

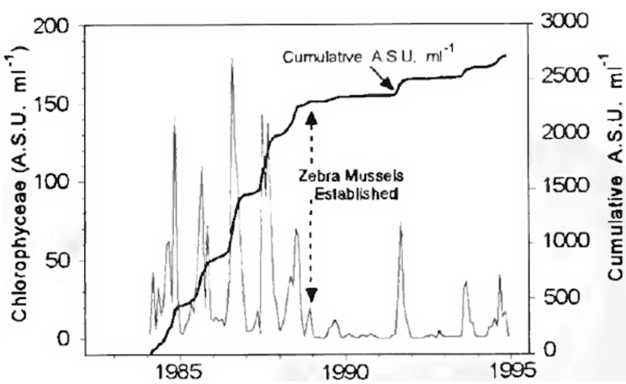

Fig. 1. *Monthly mean and cumulative densities of total Chlorophyceae in samples collected weekly through the Union Water System intake, 1984- 1994.*

The timing of this effect is consistent with the sharp declines reported in chlorophyll a and total phytoplankton for this location. The annual average chlorophyte density decreased from 38.3 A.S.U. ml^{-1} during the pre-zebra mussel years of 1984-1988 to only 5.7 A.S.U. ml^{-1} during the post zebra mussel years of 1989-1994, a reduction of 85%. There is reasonable certainty that this decline was caused by the filter-feeding zebra mussels.

Two "weedy" genera, *Pediastrum* and *Scenedesmus* have dominated the chlorophyte class for the period of record. Annual averages for both *Scenedesmus* and *Pediastrum* were significantly ($P < 0.05$) lower during the post zebra mussel period than during pre-zebra mussel period (t-tests on log-translbrmed A.S.U. values after removal of 1988 because it was a transition year).

Although these apparent effects of the zebra mussel invasion on *Pediastrum* and *Scenedesmus* were dramatic, a longer term view of the data set suggests that the zebra mussel impact was but a tiny aberration on a much more significant trend. Early data reveal peak summer densities of *Scenedesmus* and *Pediastrum* of about 400 and 2000 A.S.U. ml^{-1}, respectively, during the late 1960's (Fig. 2). The patterns of decline in these two genera were clearly different. *Scenedesmus*

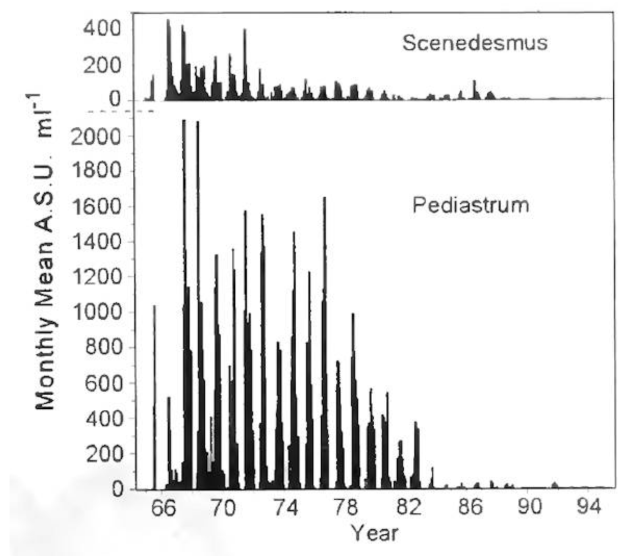

Fig.2 *Monthly mean densities of Scenedesmus and Pediastrum in samples collected weekly through the Union Water System intake.*

established a new baseline density after 1971 which persisted until 1980, after which there was a further decline to very low values in 1983, some minor increases again through 1984-87 before the crash attributed to zebra mussels in 1988-89.

In contrast, densities of *Pediastrum* remained high through the 1967-1977 period and then steadily declined to trace levels by 1984(Fig 2). At this scale, a case for a zebra mussel impact on *Pediastrum* is not plausible and for *Scenedesmus* only a little more convincing. Clearly, the most important trend is the progressive decline from the very high values of the late 1960's and early 1970's for both genera. Annual average total chlorophyte density during the 3-year periods 1970-1972 and 1983-1985 was 708 A.S.U. ml^{-1} and 44 A.S.U. ml^{-1}, respectively. It is significant that this major reduction (94%) was achieved prior to the arrival of zebra mussels.

A plot of the cumulative sum (CUSUM) of the total chlorophyte densities (Fig. 3) reveals an inflection point in the early 1970's coinciding with initial reduction of phosphorus at sewage treatment plants and with legislation controlling levels of phosphates in laundry detergents. A more important inflection point in the CUSUM curve appears at about 1981 (Fig. 3). This accelerated rate of decline of the western basin Chlorophyceae after 1980 is apparently in response to a marked decrease in Lake Erie total phosphorus concentrations beginning at about the same time.

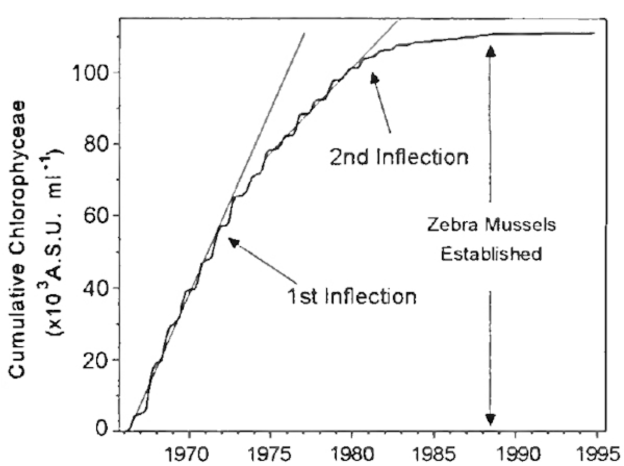

Fig. 3. Cumulative density of total Chlorophyceae (accumulated monthly means) in samples collected weekly through the Union Water System intake, 1966 to 1991.

Contemporary lake sampling programmes rarely span temporal scales adequate for definition of interdecadal environmental change (the English Lakes data sets are well known exceptions). The western Lake Erie chlorophyta data provide a practical, "real-world" example of how phytoplankton variability at one level of temporal scale is collapsed into the steady state of a higher level of temporal scale. When viewed at a temporal scale of only a few years, the impact of the zebra mussel invasion appeared dramatic.

The comparison of a few years pre-invasion data with a few years post-invasion data showed a reduction in chlorophyte density of 85%. When viewed in a much longer term context (nearly three decades), the impact of the zebra mussel arrival was barely perceptible. Much more significant declines in chlorophyte density had occurred in western Lake Erie well before the establishment of zebra mussels. Average annual chlorophyte density in the few years before the zebra mussel arrival was only about 6% of the density during the early 1970's.

Phosphorus loadings to western Lake Erie had declined to 10-15 metric tons per day by the early 1990's. It is apparent that western Lake Erie phytoplankton has responded dramatically and predictably to these reduced loads. The establishment of zebra mussels in the lake during the late 1980's can be viewed as an important but much less significant impact on western Lake Eric phytoplankton, when viewed over a relevant time period of nearly three decades. Similar conclusions may not apply to phytoplankton data from nearshore locations in the central and eastern basins of Lake Erie where the effects of phosphorus loading reductions have not been as well defined and where the zebra mussel impact has been relatively more important (Nicholls and Standke, in prep.).

Conclusions derived from analyses of these long-term, Lake Erie data sets reinforce the importance of multidecadal environmental data. Effective ecosystem management of our surface waters depends on sound interpretation of long-term data.

A more detailed account of the importance of temporal scale in the evaluation of change in western Lake Erie will be published in *Freshwater Biology* in 1997.

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