



Written Testimony of
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I am Gerald Matisoff, Professor and Chair of the Department of Geological Sciences at Case Western Reserve University. I have been asked to provide technical expertise to the Committee because of my role as Project Director of the EPA-funded grant 'Lake Erie Trophic Status' which began this summer. I have also served as Editor of the *Journal of Great Lakes Research* for the past five years and have been active in Great Lakes research since the 1970s. Attached to this document is a CV which lists my publications pertinent to Lake Erie.

Provided here are brief comments about why anoxia is occurring in the Central Basin of Lake Erie, about the effects of anoxia on the Lake Erie ecosystem, and about solutions to prevent anoxia from occurring in the future. My comments are necessarily brief, in part because we don't have complete answers to all of your questions so more detailed explanations would border on speculation, and in part because of the limited time in which to prepare my report. I would be happy to provide you with additional information or answer additional questions at a later date.

Causes of Anoxia

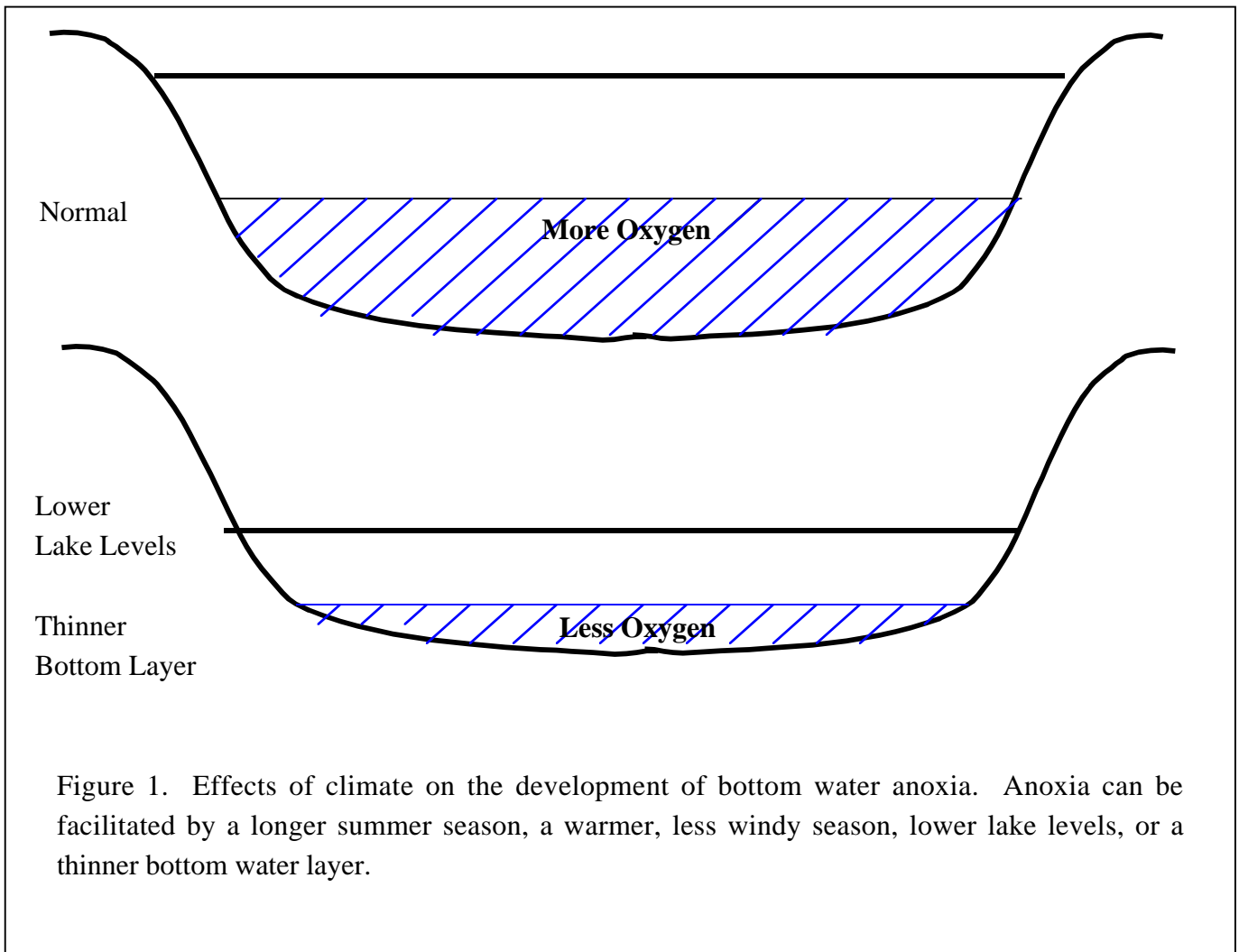
Low oxygen during the summer in the bottom waters of lakes is a natural phenomenon. What happens is that heating of the surface of a lake during the spring warms the surface water. Since warm water is less dense than cold water, it floats on top, effectively isolating the cold bottom water from the atmosphere. As a result, although the surface water can replenish oxygen by exchange with the atmosphere the bottom water can not. Bacterial respiration of organic matter in the water column and on the lake bottom consumes oxygen, so oxygen concentrations in the bottom water gradually decrease throughout the summer. Water with low oxygen concentrations are termed 'hypoxic'; if oxygen concentrations go to zero, then the water is termed 'anoxic'. In the autumn, the surface waters cool and when the densities of the surface water and bottom water are the same the water column mixes vertically destroying the 2-layer stratification and oxygen is returned to the deeper water and nutrients in the bottom water are mixed into the surface water. This process is termed 'fall overturn' and occurs in Lake Erie's central basin during August to September.

Human activity can and has exacerbated the development of anoxic bottom waters. The addition of algal nutrients such as phosphorus (and nitrogen in coastal ocean systems) from fertilizer derived from agricultural runoff and from sewage discharges has led to an increase in algal growth and a consequent increase in the amount of organic matter undergoing respiration

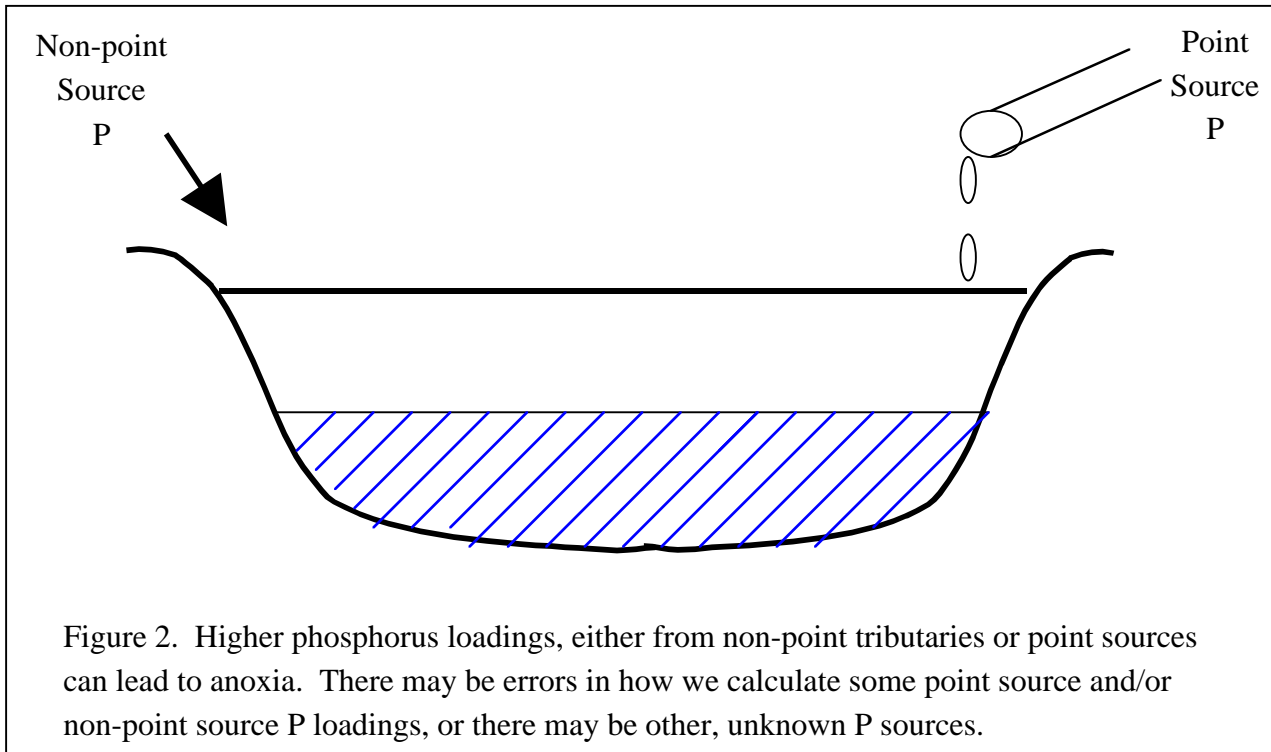
and decay during the summer. This process is termed 'eutrophication'. The Great Lakes research community played a major leadership role in the 1960s and 1970s in demonstrating eutrophication control by phosphorus load reduction. The basic approach was to synthesize a great deal of eutrophication process-oriented research into complex mathematical models of the relationship between nutrient loads and eutrophication symptoms, then those models were used to set target P loads for each lake or major embayment, then the IJC recommended programs that would achieve those loads, then the Parties implemented those programs; and when the target loads were achieved the models were post-audited and in general found to be "right on" in their predictions. For Lake Erie that target load is 11,000 metric tons of phosphorus per year. Twenty years later this process has been heralded as one of humankind's greatest environmental success stories and since then it has been copied and implemented in numerous other locations throughout the world.

Data from the IJC and from EPA indicates that the phosphorus loading goal of 11,000 metric tons per year has, more or less, been achieved on a regular basis over the last decade or two. So the question is why, if phosphorus loading goals have been met, are anoxic bottom waters recurring in the central basin of Lake Erie? My multi-investigator research project, 'Lake Erie Trophic Status' is an initial survey to begin to answer this question.

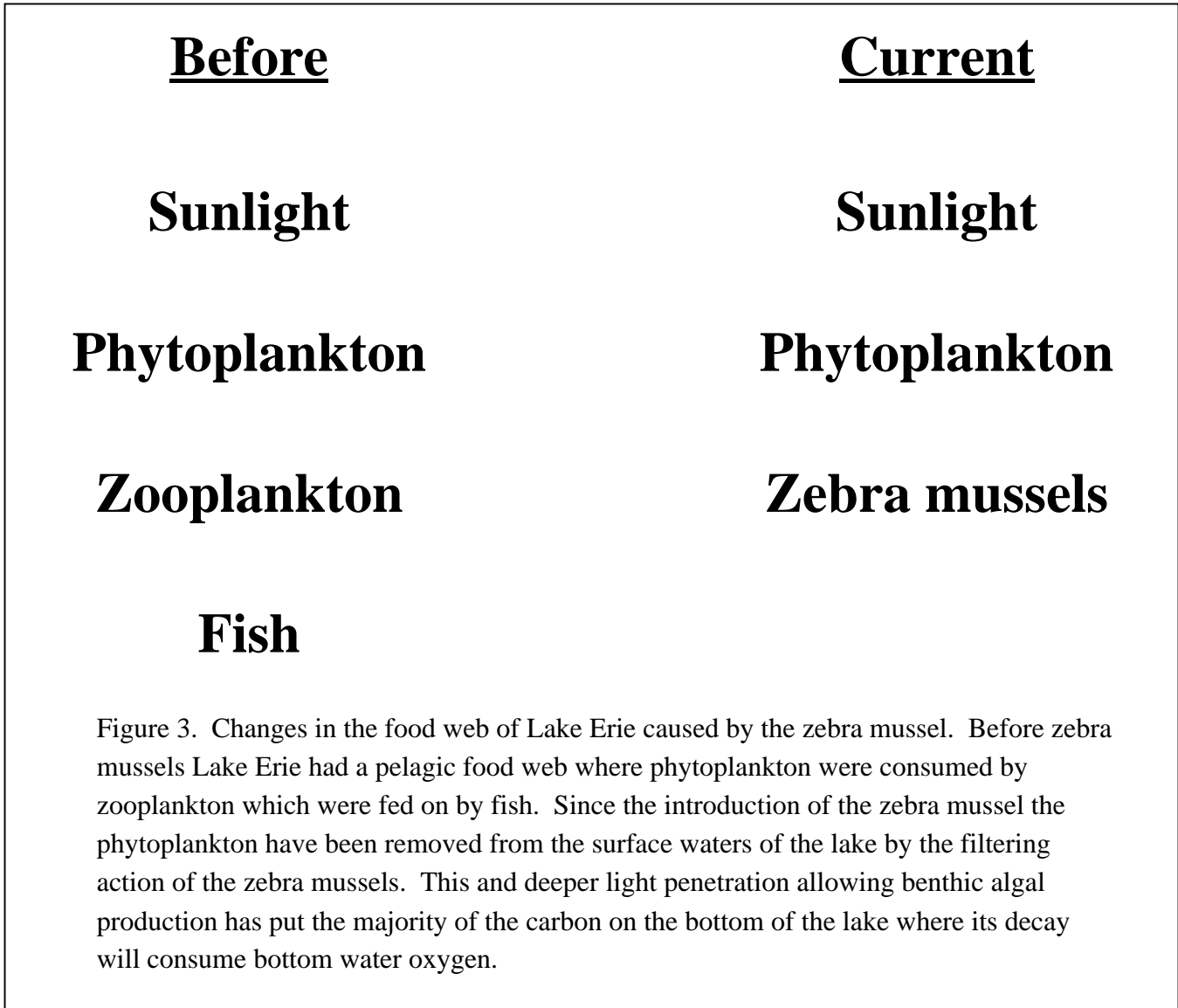
There are at least three potential explanations which are illustrated in Figures 1 through 3. The first hypothesis is that the problem is climate related (Figure 1). Variations in climate which lead to a longer time period in which the lake is stratified or leads to a thinner bottom water layer will lead to the development of anoxia in the bottom waters. These conditions include a longer summer season, a warmer, less windy season, lower lake levels, or temperature conditions that lead to the development of a thin bottom water layer. Because Lake Erie is so shallow it naturally has a thin bottom water layer and is therefore more susceptible to anoxia than the other, deeper Great Lakes.



A second hypothesis is that the actual P loading to Lake Erie is greater than we are aware of (Figure 2). This could occur because there may be unrecognized P loadings, some point source P loadings may be under-reported, or there may be errors in how some P loadings are calculated, especially from unmonitored non-point source tributaries. If P loadings are actually higher than it is thought, then anoxia may be occurring because the target goal of 11,000 metric tons per year actually has been exceeded.



The third hypothesis is that zebra mussels changed the carbon transfer system of the lake from a pelagic food web to a benthic system (Figure 3). Before zebra mussels, Lake Erie had a pelagic food web where phytoplankton (or at least the larger size fractions) were consumed by zooplankton which were fed on by fish. Since the introduction of the zebra mussel the phytoplankton have been removed from the surface waters of the lake by the filtering action of the zebra mussels. In addition, zebra mussel filtration has facilitated deeper light penetration which has allowed benthic algae and rooted aquatic plants to grow. This has put the majority of the carbon on the bottom of the lake where its decay will consume bottom water oxygen.



Effects of Anoxia

The development of bottom water anoxia has a number of undesirable consequences. Perhaps the most obvious are massive fish kills. Fish kills result from species that need cold oxygen-rich water to survive but find neither the warm surface water nor the cold anoxic water tolerable. Second, there are often taste and odor (musty smell) problems that occur because of blooms of undesirable algae. Anoxic bottom waters can cause ecosystem changes; for example, mayfly nymphs, a desired food for several fisheries, cannot survive in bottom waters that periodically go anoxic. In fact, their recent return in large numbers in the western basin of Lake Erie has been cited as evidence of the positive response of the lake to reduced phosphorus loadings. Fourth, anoxia and especially eutrophication can lead to blooms of nuisance and toxic algae and the production of water-borne toxins. Anoxia can also lead to increased phosphorus cycling and further eutrophication. Finally, anoxia results in other beneficial use impairments, such as beach closures.

Solutions to Anoxia

Since the cause(s) for the current anoxia are not known, it is premature to propose solutions to solve the problem. The key to determining an appropriate solution to anoxia is to identify the cause(s), understand how the ecosystem responds to the stresses, and then select an appropriate course of action based on potential for success, adverse effects, ease of implementation, and cost. However, if the problem is recurring and expected to continue to remain a problem in the foreseeable future, then the target phosphorus load of 11,000 metric tons per year may need to be revisited. Some other causes, for example a zebra mussel induced problem, will have other possible solution options. Some of these may be untenable or excessively expensive, such as controlling the zebra mussel population by eradication (like lampricide applications for sea lamprey control) or may include natural or induced biological control (such as predation on zebra mussels by round gobies). Climate change causes certainly

have significant implications for lake water levels and water diversions. One area of concern is that the continuing introduction of non-indigenous species has generated an ecosystem that is not in equilibrium, and the dynamic nature of the changes are difficult to predict. For example, predation on the zebra mussel by the round goby may lead to control of the zebra mussel population and reverse some of the adverse effects of the zebra mussel. This means that it will be difficult to understand sufficiently the ecosystem in order to develop an appropriate course of action. Considerably more study on nutrient cycling and on the dynamic nature of the ecosystem will be required.

Current Research

My research grant on the 'Trophic Status of Lake Erie' is an initial investigation to begin to develop and understanding of the complex interactions in this highly dynamic ecosystem. Because of the complex nature of the problem, we designed a research project that was substantially more comprehensive than the usual single investigator project. The project includes 27 principal investigators from 18 institutions. The project is primarily field-based to collect samples and data using EPA's RV Lake Guardian and the Canadian Coast Guard Vessel Limnos. The sampling effort includes the measurement of water-related attributes, sediment-related attributes, a zoobenthic inventory and includes studies to derive and extrapolate energy processing and nutrient transfer from zoobenthos through round gobies, and to quantify particle transport processes and nutrient sources among compartments.

Specific objectives include the following:

- 1) Estimate the historical frequency and extent of episodic anoxia in the bottom waters of the central basin by interpreting geochemical markers (stable isotopes, chemical species of trace materials, ostracode fragments), and other indicators of environmental change derived from sediment cores;

- 2) A simulated reconstruction of the areal extent, volume, duration, and oxygen depletion of the central basin bottom waters through the 1990s;
- 3) A lakewide quantitative assessment of dominant zoobenthos populations and distributions, especially dreissenids, oligochaete worms, chironomids, burrowing mayflies, and amphipods;
- 4) An evaluation of the accuracy and utility of remote-sense technology (side-scan sonar, ROV, videography) in analyzing sediment composition and dreissenid distribution;
- 5) A bioenergetic model of benthic energy and nutrient transfer through benthivorous round gobies;
- 6) Estimates of sediment-water boundary exchanges through sublittoral and profundal measurements of sediment oxygen demand, benthic primary production, solute and particle advection induced by physical processes, and bioturbation, and sedimentation rates;
- 7) Estimates of vertical distribution of nutrients, oxygen, phytopigments and particulate matter;
- 8) Estimates of epilimnetic and hypolimnetic primary production, respiratory demand, and cycling efficiency using both established and novel approaches;
- 9) Determination of factors and cofactors (nutrients, trace metals) limiting primary production;
- 10) Determination of lake-wide phosphorus loading, among-basin transport, and net export;
- 11) An improved conceptual model of nutrient dynamics that better explains trends in nutrient behavior, primary production, and hypolimnetic oxygen depletion than currently used models.

The field sampling is continuing throughout the summer. To date, sampling trips aboard the RV Lake Guardian occurred in June and July. Since the research efforts have been focussed on data collection, no attempt has been made yet to fully coordinate the data and/or interpret it. However, there have already been some unusual observations. Some of these key, but preliminary findings to date include the following:

- Anecdotal observations suggest that most of the dreissenid mussels were quagga mussels and not zebra mussels and they were mostly dead or in poor condition. A quantitative lake-wide

survey is planned for the August cruise. Predation on mussels by another non-indigenous specie, the round goby, may be controlling the dressenid population. Part of this study seeks to evaluate that hypothesis.

- A lot of green algae (*Spirogyra*) were found on the bottom of the lake in the nearshore eastern basin. This is similar to what was found in Saginaw Bay the year after zebra mussels were reported to have cleared the water column. Benthic algal production is probably the result of deeper light penetration and will produce oxygen. It is not known how the amounts of oxygen produced by benthic production compares with oxygen consumed by respiration of bottom algae.
- Detroit Water and Sewerage Department (DWSD) loads to the Detroit River from its main outfall were estimated to be 512 MTA in 2001. Along with the 2000 load (517 MTA), this load represents the minimum ever reported and is due to continued effluent flow rates of less than 700 million gallons per day (annual average) and declining weighted average phosphorus concentrations. These loads do not include CSOs or bypasses.
- There is no evidence for iron limitation of phytoplankton growth in the western or central basins.
- Phosphorus deficiency was assessed by alkaline phosphatase activities in the central and eastern basins. Higher activities were found in the bottom waters which, along with high concentrations of chlorophyll suggest that there is primary production occurring in the bottom water.
- Subjective evaluation of benthic invertebrate populations suggests that densities of mayfly larvae in the western basin are somewhat lower than the previous 2-3 years. Also of interest is the finding of empty shells of the Asian clam *Corbicula*, another non-indigenous specie, on beaches at 3 locations around the basin.
- Measurements of sediment oxygen demand indicate that current rates are near normal for the past decade, with oxygen removal from the bottom water at a rate of about 0.1 ppm/day.

However, the data are variable throughout the lake, with higher demands in the central basin than in the western basin and higher demands in shallower water sites than most deeper water sites.