MAUMEE BAY AND WESTERN LAKE ERIE WATER QUALITY MONITORING

A Final Report to the Lake Erie Protection Fund (Project LEPF 03-19)

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Following two decades of pollution abatement and improving conditions in Lake Erie, the health of the lake is in again in doubt. In the mid-1990s, researchers noted a troubling trend – increasing phosphorus concentrations. In 2000-01, “Dead Zones” formed in Lake Erie and made regional headlines. These phenomena are indicators of serious problems in the lake ecosystem and they are completely at odds with all previous projections of Lake Erie’s continued improvement (Charlton 2003). Predicted climate change is expected to multiply the problem. In the near future, “Dead Zones” could become the norm unless current trends in lake nutrients are reversed (Kling et al. 2003). Policy-makers and researchers now recognize the error of relaxing monitoring efforts in Lake Erie in the 1980s and 1990s. The relative lack of data from the years leading up to the present situation means that finding solutions will be even more difficult. A new emphasis on monitoring the lake is recognized as critically needed in order to develop new paradigms that can be used to explain and solve present and emerging environmental problems.

Western Lake Erie has its own unique set of environmental problems in addition to the concerns that affect the entire lake. The Maumee River, which empties into the southwest corner of the basin, is the single greatest source of suspended solids to the Great Lakes (Baker 1993). The plume of the Maumee River can stretch 50 km into the lake, its phosphorus-rich particulate load (Baker and Richards 2002), preventing sunlight from reaching aquatic plants and algae, and depositing sediments on the lake floor. In addition to this particulate load, 870,000 cubic yards of sediments must be dredged annually (Myers, et al. 2000) to maintain commercial shipping on the river. Some of the dredgings are simply transported out into the lake and dumped. Maumee River sediments are also rich in organic material. This material settles to the bottom of western Lake Erie and provides food for benthic organisms, especially mayflies and other insect larvae. Under certain conditions however, the decay of excess organic material may consume oxygen on the lake bottom faster than it can be replenished, leading to low oxygen conditions (hypoxia or “dead zones”).

Western Lake Erie has also been identified as an “Invasion Hotspot” (Colautti et al. 2003). Along with Lake St. Clair, it is usually the first place in the Great Lakes where invading species appear, and is often severely affected by their colonization. The effect of invaders such as the zebra mussel are well known throughout the Great Lakes region, but the characteristics of western Lake Erie cause zebra mussels to have additional harmful effects, namely the promotion of harmful algal blooms (Vanderploeg et al. 2001).

All of these reasons underscore the importance of monitoring the water quality of western Lake Erie and the Maumee River. The physical characteristics of western Lake Erie, however, present great challenges to any monitoring effort. Because of their greater depth, volume, and retention time, the waters of the central and eastern basins of Lake Erie change relatively slowly. In contrast, water quality in the western basin can change dramatically within days due to the influence of Maumee and Detroit River inputs, and within hours in response to changing wind speed and direction.

As an example of a monitoring challenge, it is known that "dead zones" like those reported in the central basin of Lake Erie also form over vast benthic areas of western Lake Erie when the overlying water becomes stratified (Bartish 1984). Hypoxia in western Lake Erie may occur several times each summer, but unlike the central basin, it is a transient phenomenon that can easily be missed by traditional monitoring programs. The duration and severity of these hypoxic episodes and their effects on bottom-dwelling organisms are poorly understood, but one two-week period of hypoxia is blamed for the basin-wide collapse of benthic mayfly (*Hexagenia* sp.) populations in 1953 (Britt 1954). *Hexagenia* were rare for the next 40 years until populations rebounded in the 1990s (Kreiger et al. 1996). Aside from the catastrophe of 1953, periods of hypoxia in western Lake Erie are generally thought to be too brief to cause harm. Now, however, hypoxia may again be emerging as a problem in western Lake Erie

Objectives

We proposed 4 objectives for this project:

1) *Basic Monitoring*: establishing baseline water-quality conditions in Maumee Bay and western Lake Erie.

2) *Building the Future of Monitoring:* deployment of instrument packages at various lake locations.

3) *Episodic Events* : Frequent sampling to observe algal blooms and intermittent hypoxic events as they occur.

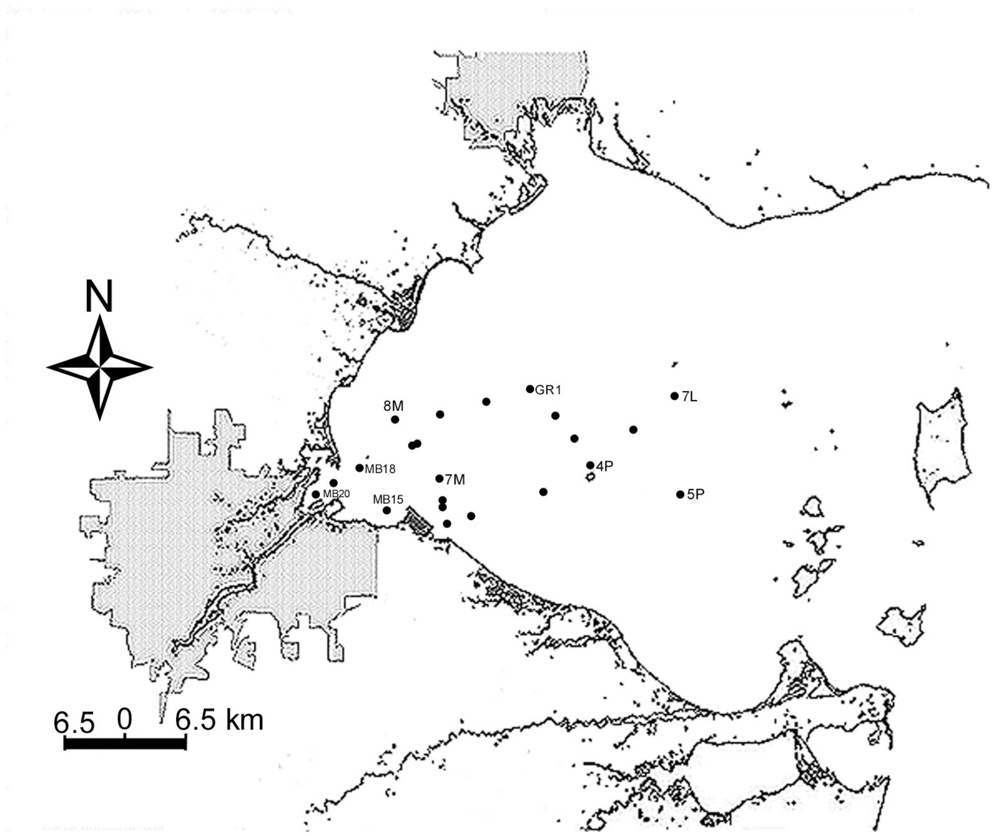
4) *Sediment Oxygen Demand of Natural Sediments and Dredgings:* Measurements of SOD in several locations including open-lake dredging disposal areas.

All 4 objectives were met during the course of the project

Methods

Basic Monitoring

During the field study period (2004-2005), we conducted monitoring cruises at 7-10 day intervals between April and October. In order to maximize the compatibility of our data with historical data sets and to provide adequate spatial coverage, we chose Maumee Bay sampling sites based on those used by Peter Fraleigh in the 1970s and offshore sites used by USGS, ODNR, and others dating to the 1930s (see figure). These locations made up six “master” stations (4P, GR1, 8M, MB 18, MB 20, 7M) that were sampled for a full complement of physical, chemical, and biological parameters. Between the master stations lay approximately 12 secondary stations that were sampled for physical parameters only. A seventh historic location (5P) was used to monitor dissolved oxygen near the lake floor. The spatial coverage of the overall monitoring effort (about 600 km^2) was determined by the speed of our boat and the sampling that could be accomplished by two or three crew members in one full day. On satellite flyover days there was an increased emphasis on physical parameters with more frequent stops (about every 2 km) to catch the spatial variability associated with the Maumee plume and algal blooms.



Monitoring locations in Western Lake Erie

Sampling: The three main components of sampling were physical, chemical, and biological parameters. Physical parameters were measured using a Hydrolab Datasonde 4a water quality multiprobe, an underwater 4-pi photometer, and a Secchi disk. The multiprobe recorded water temperature (°C) and turbidity (NTU). The photometer and Secchi disk both measured light penetration. Depending on the depth of the station, multiprobe readings were recorded at depths of 0.1m, 1m, 3m, 5m, 7m, 9m, and 0.1m above the sediments.

Water chemistry: Chemical parameters were measured using the multiprobe and by collecting lake water for laboratory analysis. The multiprobe recorded pH, conductivity ($\mu S\ cm^{-1}$), and dissolved oxygen ($mg\ L^{-1}$). Water samples were collected at discrete depths using a Van Dorn sampler. When the water column was vertically mixed, water was collected at 1m, providing consistency with Fraleigh's data (1970s). When the water column was stratified, water was collected at 1m and also below the thermocline. Water samples were collected in pre-cleaned bottles and transported back to the Lake Erie Center for processing the same day. The analysis performed were:

Total Suspended Solids/ Total Volatile Solids: A measure of the mass of suspended organic and inorganic material. Two replicate 200 ml samples were filtered on pre-combusted, pre-weighed GF/F filters. The filters were dried at 105 °C and weighed for suspended solids. Filters were then combusted at 550 °C, and weighed again to compute volatile solids. This analysis was performed in 2004 only.

Alkalinity: A measure of the acid-neutralizing capacity and indicator of river influence. 100 ml samples were titrated with 0.1 N sulfuric acid using the Gran titration.

Chlorophyll *a*: A relative measure of the biomass of photosynthetic algae in a water sample. Two 50 ml replicate samples were filtered on glass-fiber filters (GF/F). Filters were desiccated and stored in an ultra-cold freezer (-70 °C). Chlorophyll was extracted from the filters using dimethylformamide and analyzed fluorometrically on a Turner fluorometer.

Total and Dissolved nutrients: 75 ml samples were filtered through a 0.45 micron filter and then preserved by freezing in pre-cleaned bottles. 100 ml raw-water samples were frozen. Filtered and un-filtered samples were delivered frozen to the National Center for Water Quality Research in Tiffin, OH for the analysis of total phosphorus, soluble reactive phosphorus, total nitrogen, nitrate, nitrite, ammonia, sulfate, silica, and chloride.

Zooplankton: Duplicate samples of zooplankton were collected by vertical hauls of a 0.5 m diameter, 112 μm mesh plankton net and preserved in 4% formalin. The net was equipped with a flow meter to allow quantitative analysis of samples. Zooplankton samples were examined under a stereo microscope for the appearance of the exotic species *Cercopagis pengoi*, *Daphnia lumholtzi*, or any new invaders.

Phytoplankton (algae): Raw water samples containing phytoplankton were preserved with Lugol's solution and with formalin. Many of these samples were examined under a compound microscope to identify the major phytoplankton species present during algal blooms. Zooplankton and phytoplankton samples were archived for use in future studies.

Sediment Oxygen Demand: Short sediment cores were collected at several locations ranging from Maumee Bay to West Sister Island and across sediment types ranging from sand, to disposed dredgings, to organic-rich silt. Cores were collected in Plexiglas tubes by SCUBA divers in 2004 and by Ekman dredge in 2005. Cores were transported to the Lake Erie Center where SOD was determined using a dissolved oxygen microelectrode probe (Revsbech 1989)

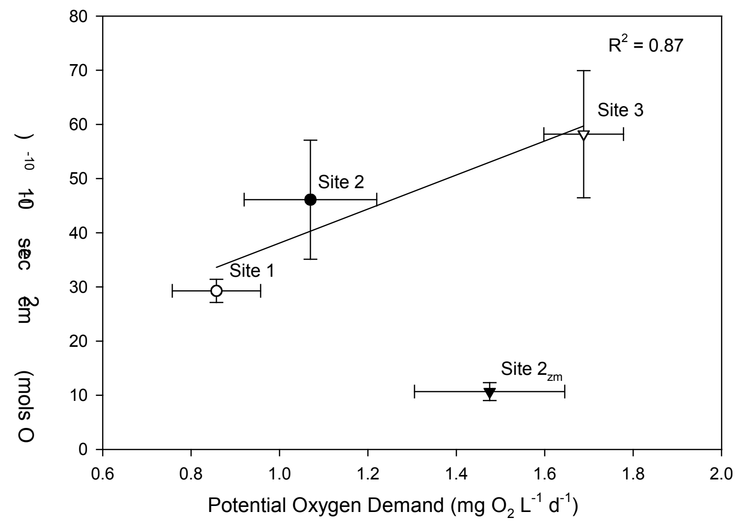
Monitoring Instruments: In situ temperature loggers were placed from surface to lake bottom in several locations to help record stratification events. Temperature loggers were retrieved and downloaded at the end of each season. A dissolved oxygen logger (Greenspan) was deployed to record intermittent hypoxia near the lake sediments.

Episodic events: In keeping with our "rapid response" philosophy, cruises were be added as needed targeting stratification events in June and July, potentially harmful algal blooms in August, and the *Cercopagis* population peak in August/September.

Results

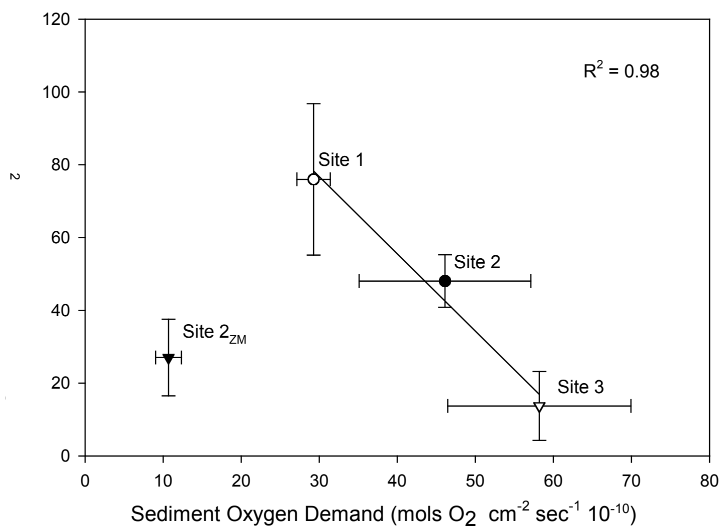
Basic Monitoring: Between April and October of 2004-05, 1,511 sets of measurements were made in Maumee Bay and Western Lake Erie. These are mainly records of multiprobe data, but of these sets 140 contain chemistry data and have associated zooplankton and phytoplankton collections. Monitoring datasets are available at the University of Toledo/ Lake Erie Center website: **http://www.lakeerie.utoledo.edu/html/gis.htm,** including US EPA-sponsored data collections from 2002 and 2003.

Sediment Oxygen Demand: Measurements made in 2004 suggested that SOD differed between locations in Western Lake Erie, with higher SOD found offshore at sites with fine-grained sediments than nearshore sites with more sandy sediments. SOD did not change significantly over time and was not higher at dredge disposal locations. In 2005, a comparison was made between three different methods of measuring oxygen demand. Duplicate sediment cores were incubated for Core Respiration, Sediment Oxygen Demand, and Potential Oxygen Demand. The results of the study suggested that there may be other factors that prevent the methods from being directly comparable (IAGLR presentation, Bridgeman, et al. 2006).



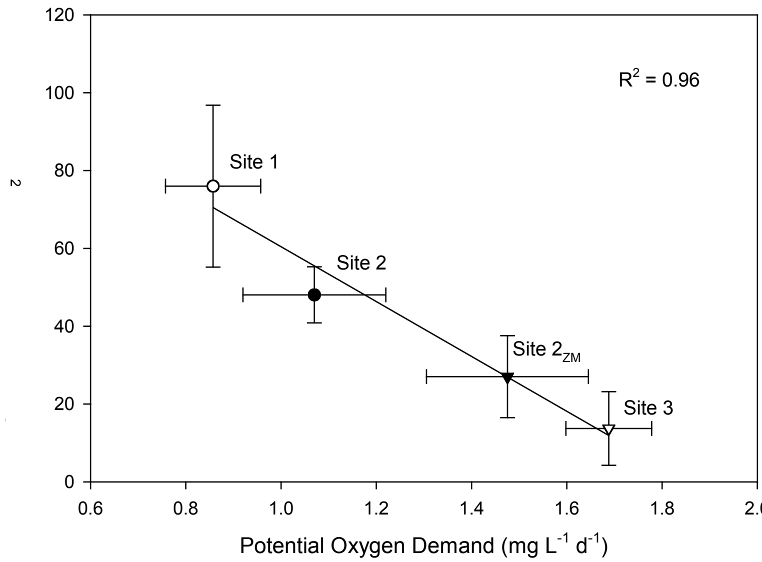
Sediment Oxygen Demand vs. Potential Oxygen Demand

SOD and POD were positively correlated except for Site 2_{ZM} which had a thick layer of dreissenid mussels. Mussel respiration caused depletion of oxygen in the water above the sediment water interface (2 mg/L) resulting in a lower flux of oxygen across the sediment-water interface.



Core Respiration vs. Sediment Oxygen Demand

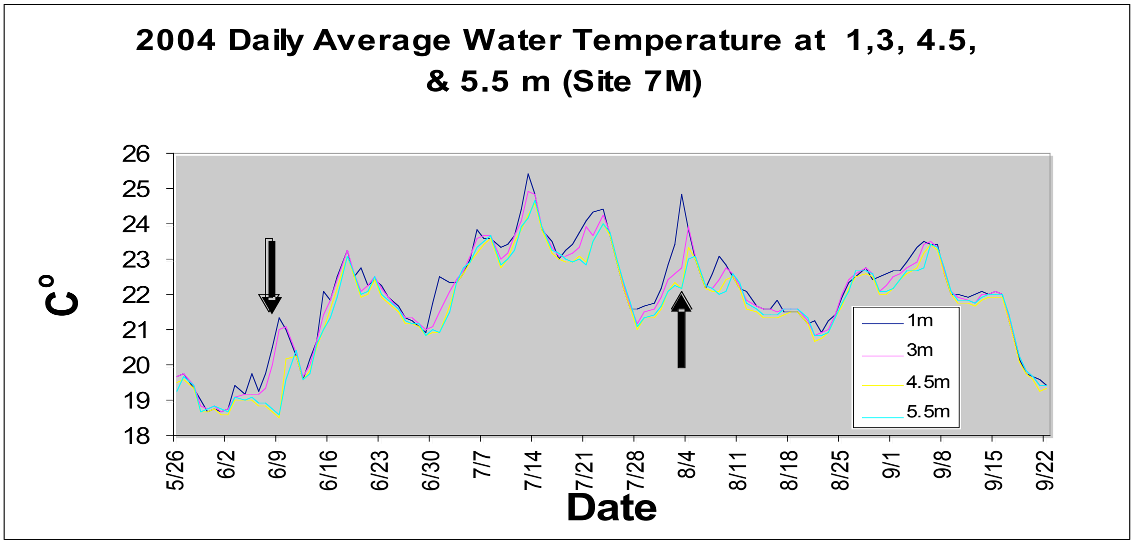
CR and SOD were negatively correlated except for Site 2_{ZM}. CR is an integral measurement of all the oxygen-consuming processes at the sediment surface (sediment + invertebrates), whereas SOD measures only sediment processes. Therefore, it was expected that Site 2_{ZM} would not correlate well with the other non-dreissenid sites.

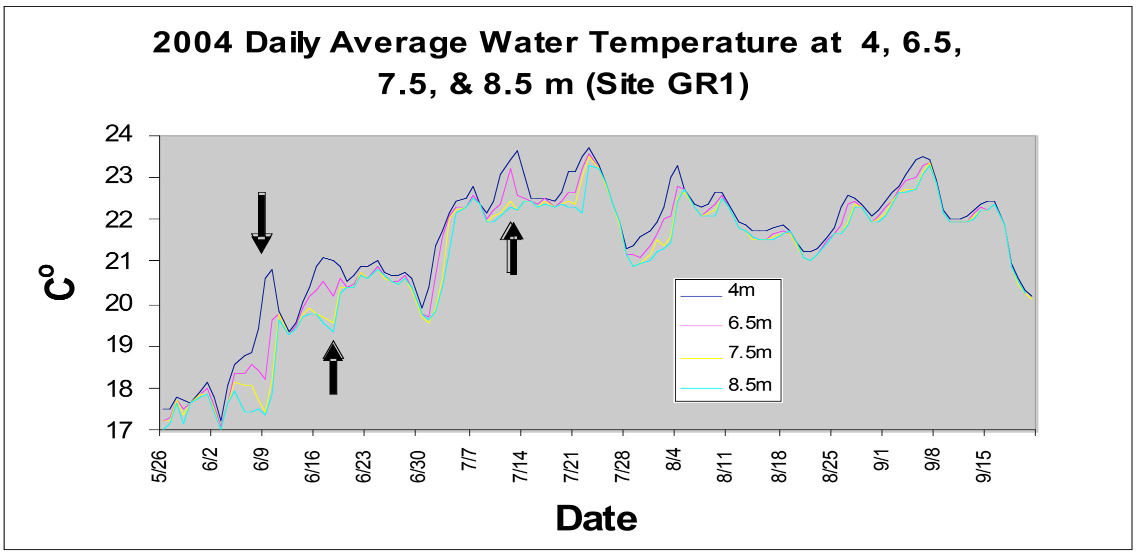


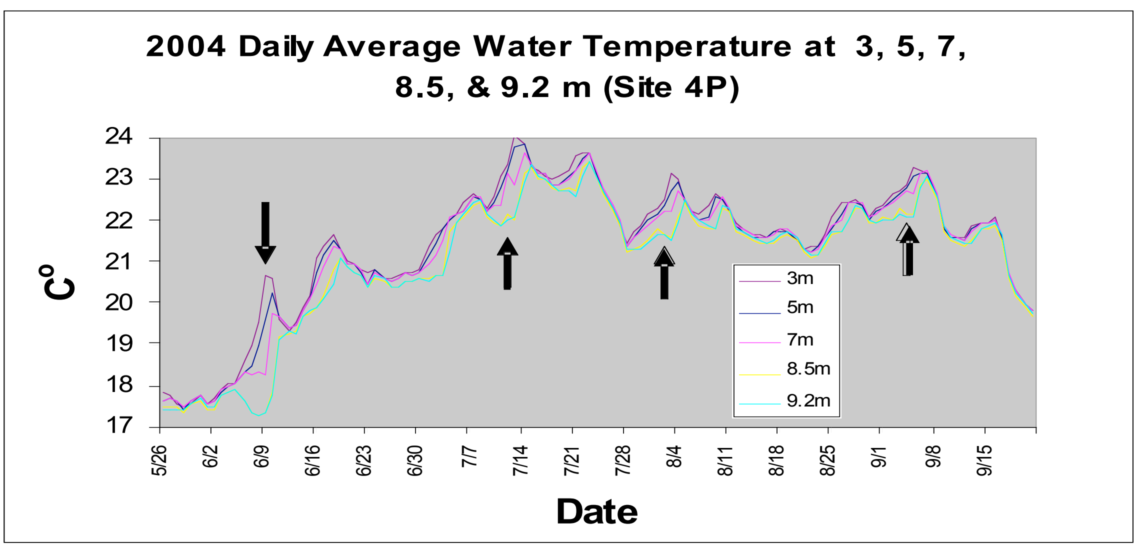
Core Respiration vs. Potential Oxygen Demand
CR and POD were negatively correlated. The negative relationship between core respiration and both POD and SOD runs counter to our predictions, suggesting that more studies are needed to understand the relationship between the 3 methods of determining oxygen demand of sediments and benthos.

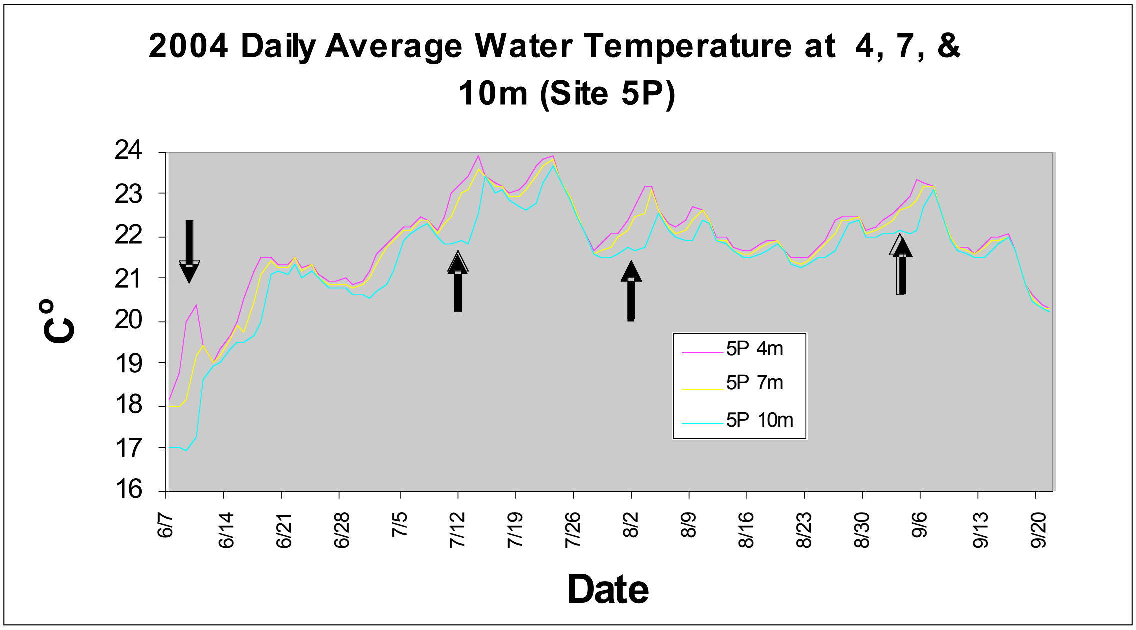
<u>Episodic Events</u>
Temperature loggers installed at various depths at 4 locations in 2004 revealed evidence of several brief events during which the western basin became thermally stratified (note black arrows on figures), probably as the result of summer heat waves accompanied by low wind speed. In general the stratified periods coincided at all sites, but deeper sites may have experienced more frequent stratification events due to the requirement of higher wind energy to cause complete vertical mixing. At site 5P, periods of hypoxia recorded by the dissolved oxygen logger, generally correspond with periods of thermal stratification. Additional periods of stratification were observed in 2005. Unfortunately, loggers at one site (GR1) were lost and the dissolved oxygen logger malfunctioned. As a result, we do not have a continuous record of bottom DO in 2005.

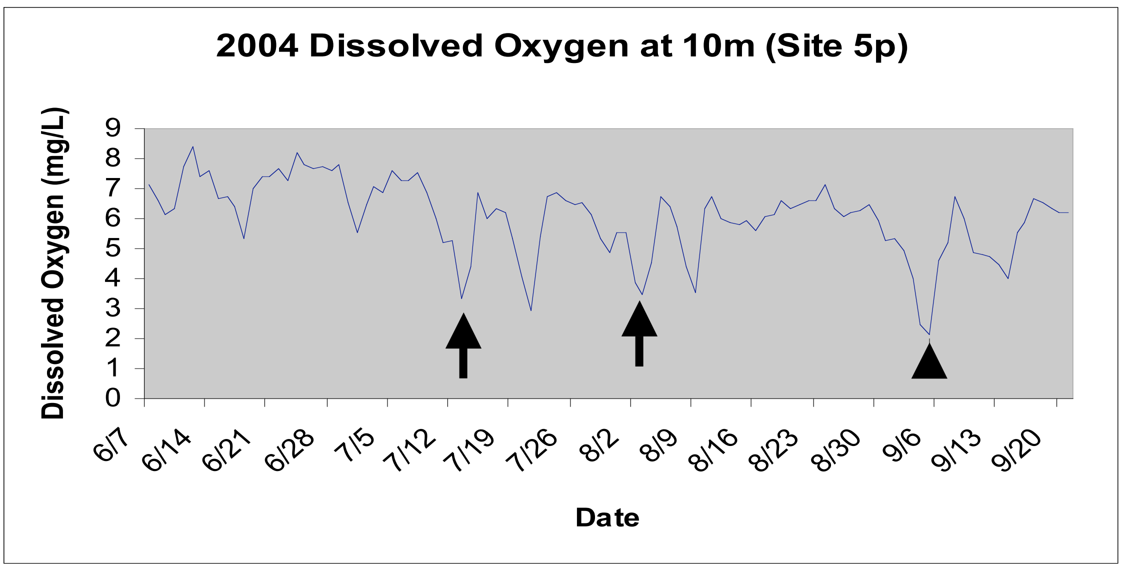
Blooms of the cyanobacteria *Microcystis* sp. were observed in 2004 and 2005, but did not reach the proportions of the bloom observed in 2003. Chlorophyll data from these blooms are included in our on-line data and preserved algal samples from the bloom await further analysis.

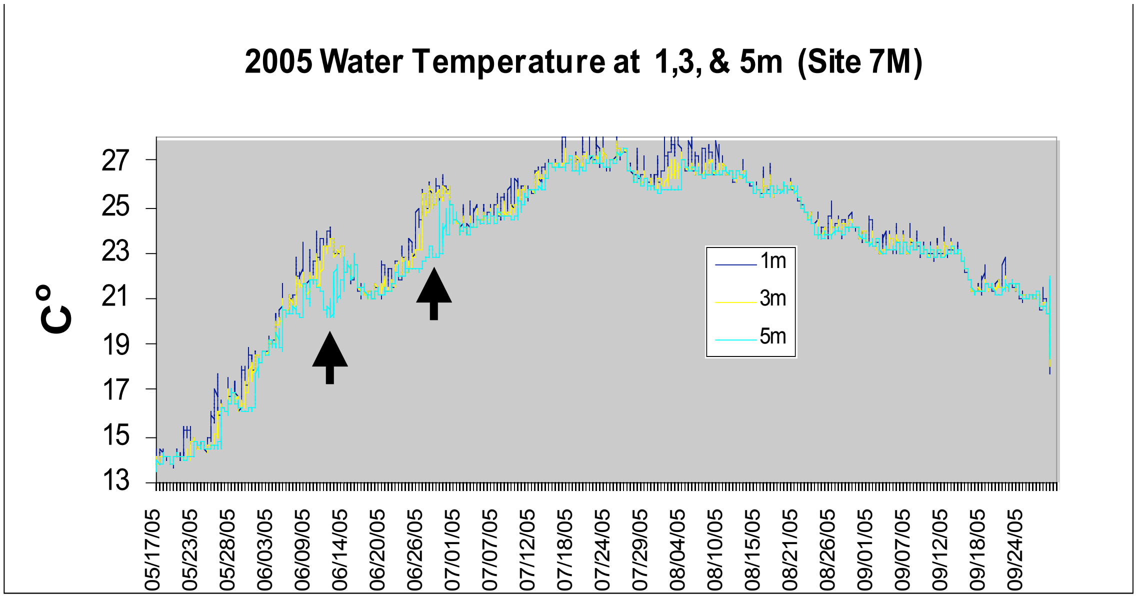

2004 Daily Average Water Temperature at 1,3, 4.5, & 5.5 m (Site 7M)
C°
Date
1m
3m
4.5m
5.5m
5/26
6/2
6/9
6/16
6/23
6/30
7/7
7/14
7/21
7/28
8/4
8/11
8/18
8/25
9/1
9/8
9/15
9/22


2004 Daily Average Water Temperature at 4, 6.5, 7.5, & 8.5 m (Site GR1)
C°
Date
4m
6.5m
7.5m
8.5m


2004 Daily Average Water Temperature at 3, 5, 7, 8.5, & 9.2 m (Site 4P)
C°
Date
3m
5m
7m
8.5m
9.2m


2004 Daily Average Water Temperature at 4, 7, & 10m (Site 5P)
24
23
22
21
20
19
18
17
16
C°
5P 4m
5P 7m
5P 10m
6/7
6/14
6/21
6/28
7/5
7/12
7/19
7/26
8/2
8/9
8/16
8/23
8/30
9/6
9/13
9/20
Date


2004 Dissolved Oxygen at 10m (Site 5p)
Dissolved Oxygen (mg/L)
9
8
7
6
5
4
3
2
1
0
6/7
6/14
6/21
6/28
7/5
7/12
7/19
7/26
8/2
8/9
8/16
8/23
8/30
9/6
9/13
9/20
Date


2005 Water Temperature at 1,3, & 5m (Site 7M)
C°
27
25
23
21
19
17
15
13
1m
3m
5m
05/17/05
05/23/05
05/28/05
06/03/05
06/09/05
06/14/05
06/20/05
06/26/05
07/01/05
07/07/05
07/12/05
07/18/05
07/24/05
07/29/05
08/04/05
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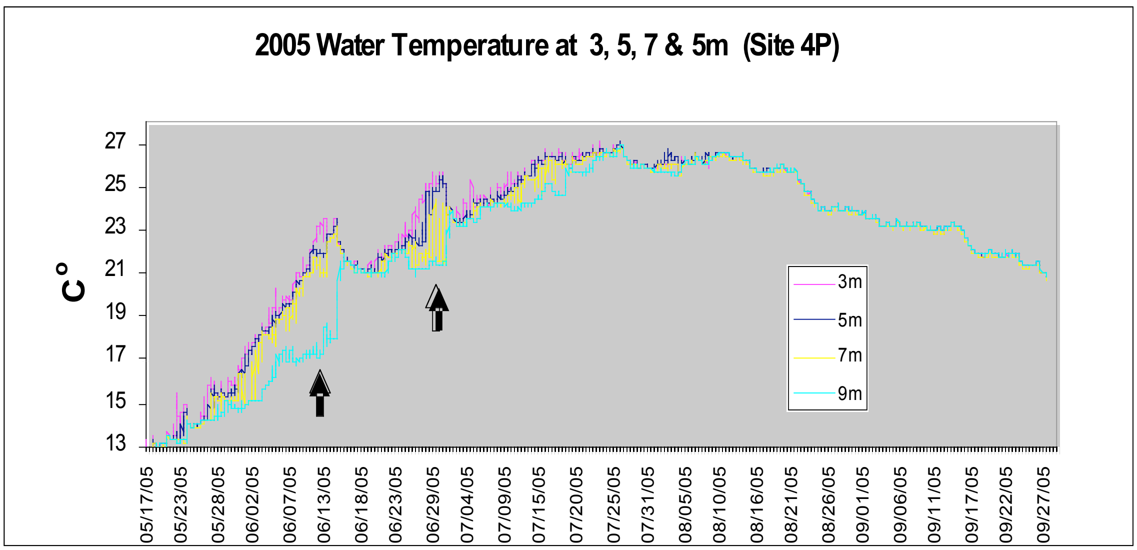
09/12/05
09/18/05
09/24/05


2005 Water Temperature at 3, 5, 7 & 5m (Site 4P)
C°
27
25
23
21
19
17
15
13
3m
5m
7m
9m
05/17/05
05/23/05
05/28/05
06/02/05
06/07/05
06/13/05
06/18/05
06/23/05
06/29/05
07/04/05
07/09/05
07/15/05
07/20/05
07/25/05
07/31/05
08/05/05
08/10/05
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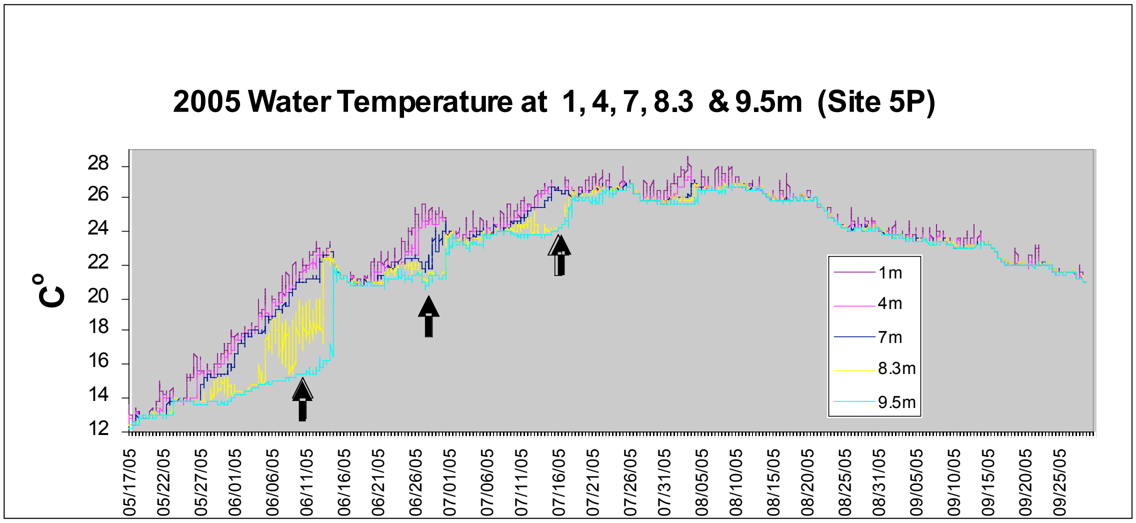
09/22/05
09/27/05



Products

Besides the large dataset available on-line, this project has resulted in several presentations at professional conferences and manuscripts published or in preparation in peer-reviewed scientific journals. Because this was a continuation of a monitoring program begun in 2002, the online data and some publications include years prior to 2004.

Publications

Rinta-Kanto, J.M., A.J.A. Ouellette, M.R. Twiss, G.L. Boyer, T.B. Bridgeman, and S.W. Wilhelm. 2005. Quantification of toxic *Microcystis* spp. during the 2003 and 2004 blooms in Western Lake Erie*. Environmental Science and Technology* 39, 4198-4205.

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Presentations

2005 American Society of Limnology and Oceanography, National Meeting (Mayer, C.M., R. Johnson, R. Lohner, L. Rudstam, E. Mills, T. Bridgeman, and S. Heckathorn) Biological and physical factors affecting benthification in lakes.

2005 International Association of Great Lakes Research, Annual Conference (Bridgeman, T.B.) The *Microcystis* blooms of western Lake Erie 2003-2004.

2005 Estuarine Research Federation (Bridgeman, T.B., D.W. Schloesser, J.J. Ciborowski, S.A. Ruberg, and M.A. Thomas) Hypoxia and benthic ecology in western Lake Erie. (Symposium - invited).

2006 2006 Lake Erie Millenium Conference (Bridgeman, T. B., Don W. Schloesser, Ann E. Krause) Hypoxia and Benthic Ecology in Western Lake Erie. (invited)

2006 International Association of Great Lakes Research, Annual Conference (Bridgeman, T. B., C. M. Mayer, D. W. Schloesser, K. M. DeVanna1, Rachel N. Lohner) Oxygen Demand of Western Lake Erie Sediments and Benthos: A Methods Comparison.

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