# Respiration and Production Changes in Lake Michigan

*Kaitlyn Driza, Bopaiah Biddanda, Angela Defore, Scott Kendall, Maggie Weinert, Eric Strickler, Gary Fahnenstiel*

Grand Valley State University -- Annis Water Resources Institute, 740 W. Shoreline Drive, Muskegon, MI, 49441

## Abstract

Lakes are key players in the global carbon cycle, with freshwater ecosystems being highly reactive sites processing a significant portion of the global carbon flow between land and the ocean (Cole et al. 2007). Over the last few years, we have studied the inter-annual gross primary production (GPP) and respiration (R) occurring at four locations along a land to lake gradient in Lake Michigan: a Laurentian Great Lake. Discrete measurements were employed to detect changes in dissolved oxygen which can then be used to estimate GPP and R of carbon. Results suggest that both GPP and R decrease with increasing distance from the shore. However GPP decreases at a much faster rate than R. This leads to near-shore net autotrophic systems giving way to net heterotrophic systems offshore. This gradient shows that terrigenous inputs of carbon and nutrients support significant bacterial metabolism and phytoplankton production in the lake, while planktonic respiration is at the mercy of the current as well as past primary production in Lake Michigan. Interestingly, R increased more than GPP during warmer years and GPP declined more than R during a cooler year, suggesting potential enhancement of R over GPP in Lake Michigan if the generally warming trend continues. Such a trend would lower the GPP/R ratio, rendering the lake a net source of released CO2 to the atmosphere. This could cause the current level of fisheries to become unsustainable. Further monitoring will lead to a better picture of the carbon cycle in Lake Michigan and possibly identify any changing environmental conditions.

## Introduction

Organic matter is a primary regulating component in the carbon flux through all aquatic ecosystems, as organic matter can be produced or destroyed through the major metabolic pathways of gross primary production (GPP), and respiration (R) (Cole et al. 2000). If GPP is greater than R the ecosystem is considered to be autotrophic and it may export or sequester carbon in the form of organic matter. In contrast, if R exceeds GPP, the ecosystem is considered heterotrophic and must be supported by imported organic matter (Ricklefs and Miller 2000). Some bodies of waters, such as Lake Michigan, receiving significant river discharge, will form a distinct land to lake gradient where near-shore net autotrophic systems give way to net heterotrophic systems offshore (Biddanda unpublished). Historical observations show that these environmental gradients form by DOC buildup and drawdown, episodic re-suspension events, and major inputs of terrigenous matter via rivers and lakes (Biddanda & Cotner 2002). The objective of this study was to explore the long-term trends in GPP and R, to capture lake metabolism response to changing conditions such as surface water temperature over time, and any episodic events such as re-suspension in Lake Michigan along a land to lake gradient.

Literature Cited

Biddanda, B.A., Cotner, J.B. 2002. Love Handles in Aquatic Ecosystems: The Role of Dissolved Organic Carbon Drawdown, Resuspended Sediments, and Terrigenous Inputs in the Carbon Balance of Lake Michigan. Ecosystems 5: 431-445.

Cole, J.J., Prarie, Y.T., Caraco, N.F., McDowell, W.H., Tranvik, L.J., Striegl, R.G., Duarte, C.M., Kortelainen, P., Downing, J.A., Middelburg, J.J., Melack, J. 2007. Plumbing the Global Carbon Cycle: Integrating Inland Waters into the Terrestrial Carbon Budget. Ecosystems 10: 171-184.

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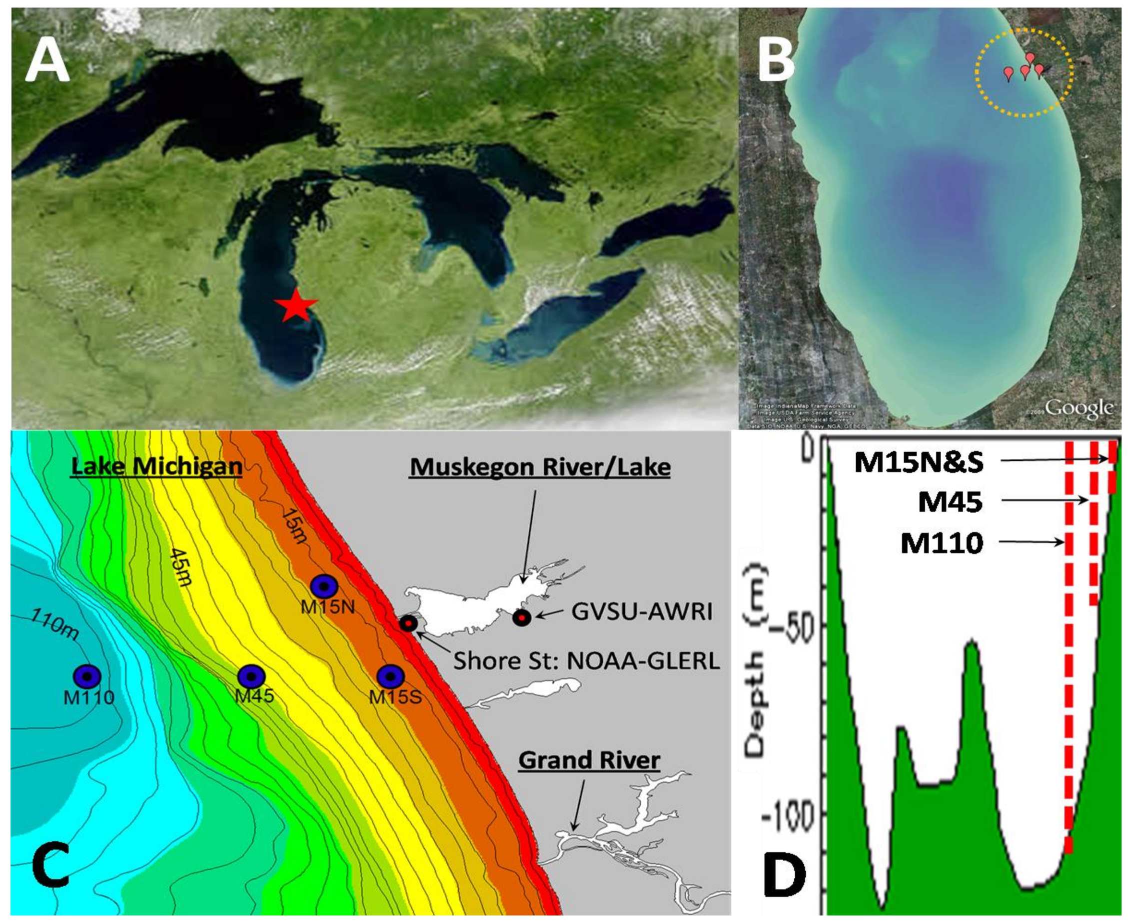
Figure 1 (a) the Great Lakes, (b) southern Lake Michigan, (c) the offshore area of Muskegon along isobaths 15-110m (shows NOAA and GVSU facilities), and (d) position of sites in the water column of Lake Michigan along an east-west transect extending from Muskegon.



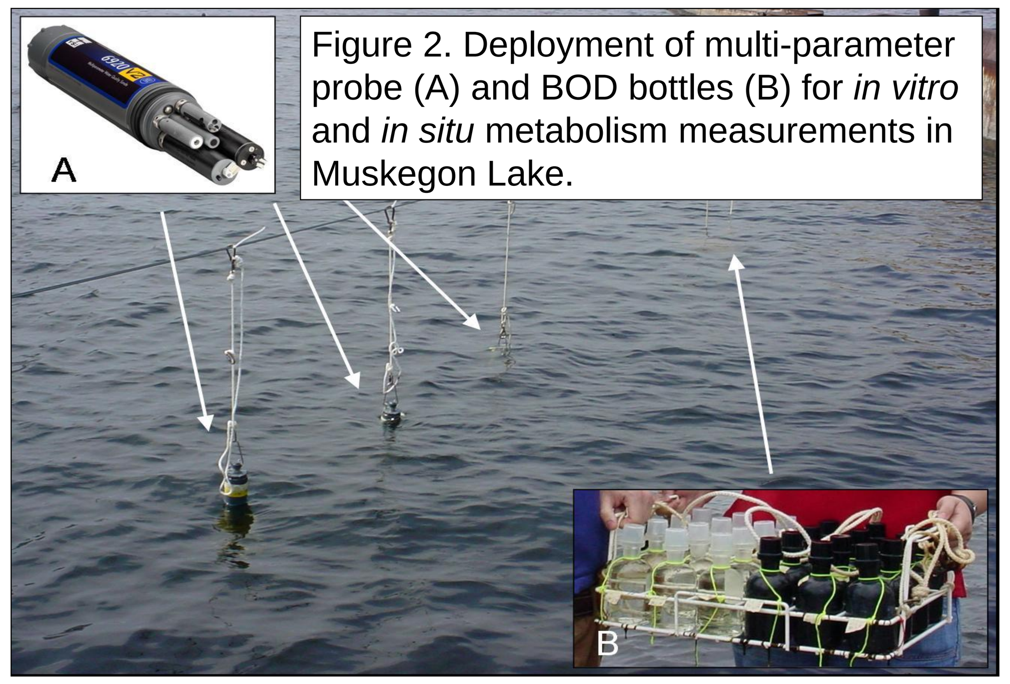
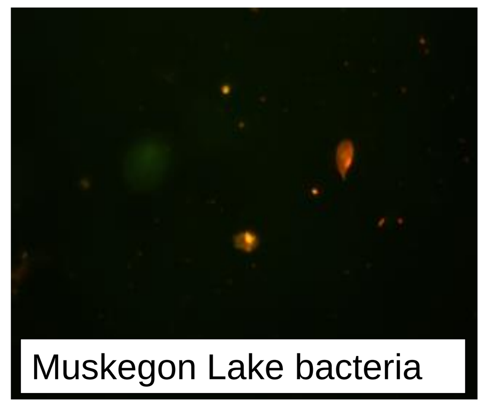



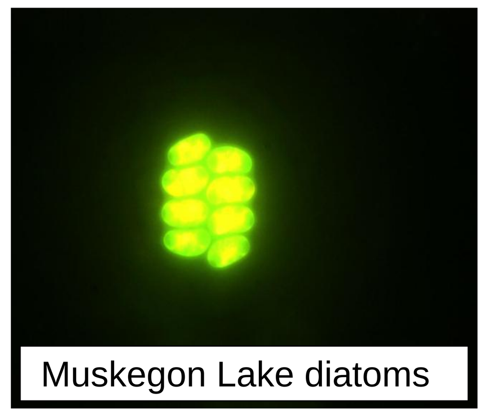
Figure 2. Deployment of multi-parameter probe (A) and BOD bottles (B) for *in vitro* and *in situ* metabolism measurements in Muskegon Lake.

## Study Site

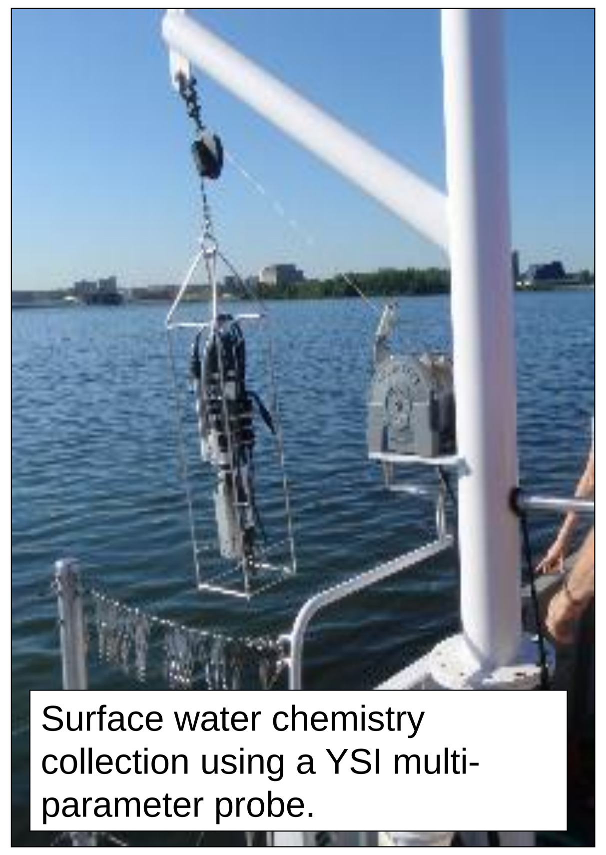
Three study sites in Lake Michigan, a Laurentian Great Lake, were chosen based on water depth. M-110 (N 43° 11.99, W 86 ° 34.19), M-45 (N 43° 12.370, W 86° 26.980), and M-15 (N 43° 11.29, W 86° 20.64) each had a water depth of 110 m, 45 m, and 15m respectively. A fourth site in Muskegon lake (N 430 13' 59.45, W 860 17' 25.42) completed the land to lake gradient.



Muskegon Lake bacteria



Muskegon Lake diatoms

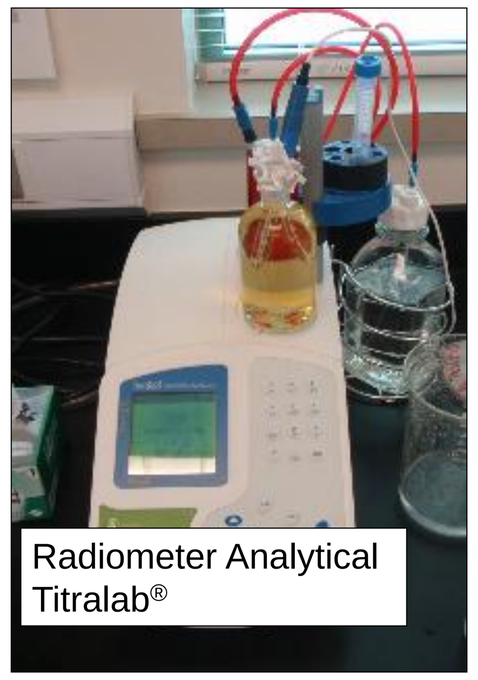


Surface water chemistry collection using a YSI multi-parameter probe.

## Sampling Protocol

Surface water samples were collected at a depth of 0.5 meters at 3 sites on Lake Michigan and 1 site on Muskegon Lake (Figure 1). Prior to sample collection, basic water chemistry (temperature, pH, conductivity, depth, dissolved oxygen, and turbidity) was measured using a YSI 6600 Multi-parameter probe. Additionally, photosynthetically active radiation was measured on a Li-Cor quantum sensor. Windspeed, precipitation and barometric pressure was recorded from nearest NOAA monitoring station. Water samples were placed in acid washed bottles and transported on ice to the Annis Water Resources Institute for analysis of biological oxygen demand (BOD), dissolved organic carbon (DOC), bacterial production, and bacterial abundance. Oxygen uptake in untreated and unfiltered water samples was measured in quadruplicate in clear and darkened BOD glass bottles (~300 ml). The bottles were incubated for 24 hrs *in situ* in the lake. Changes in oxygen were then measured using Winkler titration with endpoint detection using a Radiometer analytical Titralab®. Oxygen consumption in the darkened bottles represents community R, and the light bottles were assumed to represent net primary production (NPP).

Control, 24 hour light, and 24 hour dark BOD bottles prepared for titration.



Radiometer Analytical Titralab®

## Results

Metabolism Over the Years

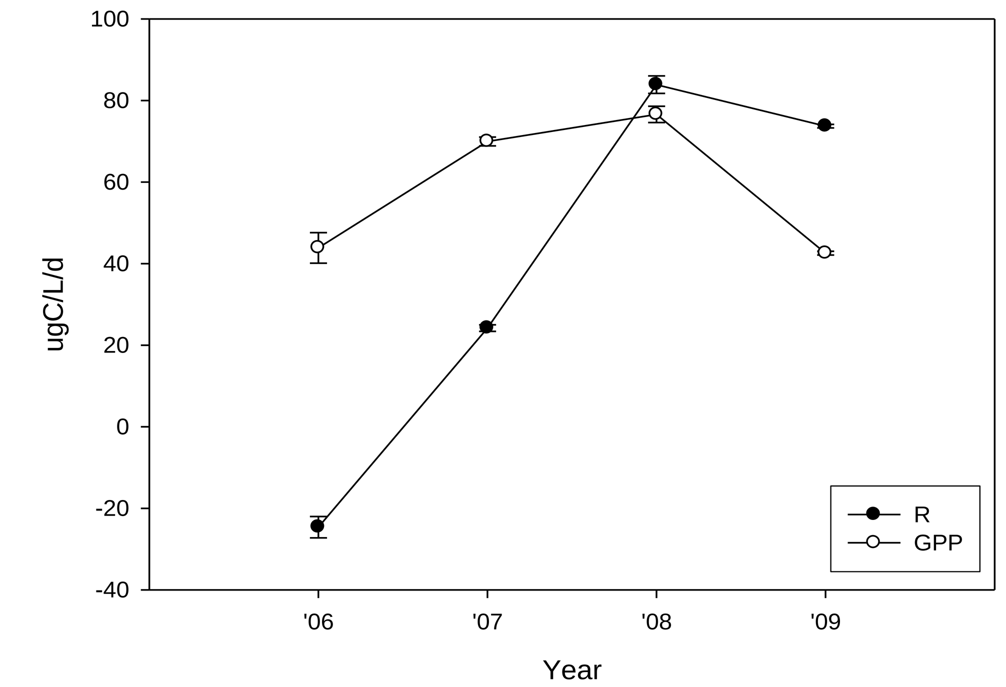



Figure 3: Average Metabolism Rates in Lake Michigan

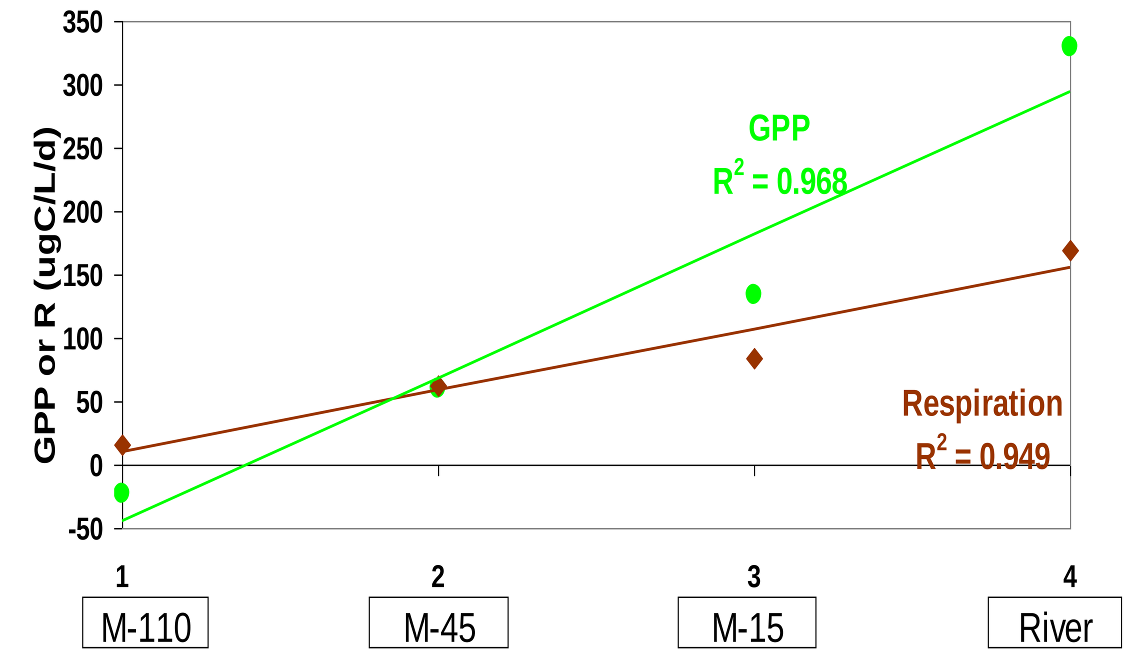



Figure 4: Average Metabolism rates at each Lake Michigan transect (2006-2009)

Analysis shows that both production and respiration rates are increasing. However, R is increasing at a greater rate than GPP, and even surpassing GPP in the past two years.

Both GPP and R decrease along the land to lake gradient, but GPP decreases at a faster rate than R.

## Conclusion

The study shows Lake Michigan forms a distinct land to lake gradient where metabolism rates decrease when traveling further offshore. This demonstrates that production is supported by terrigenous inputs, while metabolism must be sustained by currents and past production.

Metabolism rates are increasing over the years, which could be due the rising surface water temperatures. Respiration has even surpassed production in the past two years, which is rather odd. There needs to be a balance between the two rates. If Respiration exceeds production, there is a net export of $CO_2$ into the atmosphere, which can lead to increasing global temperatures and hence even more respiration.

## Future Research

•Further studies should focus on gathering long term data that will show the metabolism trends within the water over years.

•The analysis of the water chemistry and how it affects metabolism rates could also be explored. Data such as the chemical composition of the water and any pollution factors that enhance or decrease metabolism could be looked into