Henry David Thoreau’s vision of a lake as “Earth’s Eye”:
Balance of Production and Respiration in a Changing Lake Michigan Watershed: Linking Historic Data to Real-time Observations

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Traditional (a) and Modern (b) Views of the Role of Inland Lakes in the C Cycle

Freshwater ecosystems are major sites of C processing!
Aquatic microorganisms link terrestrial organic matter and nutrients to aquatic productivity (Biddanda and Cotner, Ecosystems 2002).

Rivers link Land-derived C & Nutrients to the Lake via Aquatic Microbes!
Trends from 2002-2008
- Muskegon lake outward

Average R and GPP (2002-2008)

- GPP
- R

$R^2 = 0.95$  
$R^2 = 0.94$
Methods

• Respiration (R) and Production (P) were measured by tracking changes in dissolved oxygen concentrations in BOD bottle incubations under in situ conditions over a daily cycle.
• R = Dark bottles
• NPP = Light Bottles
• GPP = R + NPP
Plankton Metabolism: Land to Lake Gradient in Lake Michigan

Decreasing Gross Primary Production Along the Land to Lake Gradient
Decreasing Plankton Respiration Along the Land to Lake Gradient
Plankton Metabolism: Land to Lake Gradient in Lake Michigan

Average R and GPP (2002-2008), Lake Michigan Transect

River: GPP > R (C sink)

Lake: GPP < R (C source)

Production drops much faster than R along the Land to Lake Gradient!
Muskegon Lake AOC: Seasonal Study of Production and Respiration

• AOC by USEPA
  – environmental impairments
  • Direct discharge of industrial and municipal waste
    – Nutrient enrichment and discharge of organic chemicals
Seasonal GPP and R Data for Muskegon Lake (2009-10)

Net Productivity
spring-summer

Autotrophy spring-summer

Heterotrophy fall-winter
Why study Production and Respiration?

“Production and respiration are two sides of the same metabolic coin – the yin an yang of the biosphere”

Need for Real-time Observatories...
EPA-GLRI
Muskegon Lake Observatory Objectives

1. Establish a continuous time-series monitoring system to measure biological, chemical and physical characteristics.
2. Link data to regional/global observatory networks
3. Enable research, training, education and outreach
Observatory Components

- Surface Buoy w/ Wind, Temp., Pressure, Precipitation, Humidity Sensors
- Subsurface Buoy w/ Sensors
  - CTD, Turbidity
  - PAR, Chlorophyll
  - pH, Phycocyanin
  - DO, Nitrates
  - CDOM
- Temp Nodes (6)
- Acoustic Doppler Current Profiler
Parameters being measured

**Biological Parameters**
- Chlorophyll (algae)*
- Phycocyanin (cyanobacteria)*

**Key nutrients:**
- Nitrate
- Colored dissolved organic matter (CDOM)
- Phosphates ?....

**Other Parameters**
- Dissolved oxygen*
- PAR (light)
- Turbidity
- pH
- Conductivity
- Temperature*
- Depth
- Hydrodynamics (e.g., current speed/direction)

WetLabs
Cycle P Analyzer
See talk by Tom Holcomb today in Session – Toxins and Monitoring
2011: Temperature in Muskegon Lake

Warmer surface waters overlying cooler bottom waters July-Sept.
2011: Chllorophyll $a$ and Phycocyanin

Increasing algal and cyanobacterial biomass with August peak
2011: Dissolved Oxygen

Development, persistence and decay of summer bottom water Hypoxia
Presence of lake-wide summer Hypoxia in bottom waters
Observations

• Findings from Discrete/Seasonal Measurements
  • Microbial respiration is a major fate of primary production in Lake Michigan and Muskegon Lake.
  • There are clear spring-summer net autotrophy and fall-winter net heterotrophy trends.

• Findings from Continuous Lake Observatories:
  • Muskegon Lake: Spring through fall, surface warms, biomass builds up and bottom water hypoxia appears and disappears.
  • Nearshore Lake Michigan...NOAA-GLERL?
  • Cross-Lake Processes...UWM-GLWI?
  • Continuous Lake Observing Systems are essential for Understanding Dynamic Ecosystem Change
Questions?

Muskegon Lake Sentinel: [www.gvsu.edu/wri/buoy/](http://www.gvsu.edu/wri/buoy/)

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A lake is the landscape’s most beautiful and expressive feature. It is earth’s eye: looking into which the beholder measures the depth of his own nature.”

Henry David Thoreau, WALDEN, 1854