Science-Based Monitoring of the Nearshore Zone: Lake Simcoe (Ontario, Canada)

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Why Science?

- Environmental issues concerning the ***quality*** and ***quantity*** of freshwater are at the forefront of media attention, scientific interest, and public concerns
- **We need scientific data to:**
  – Identify the problem
  – Determine the cause (Natural? Human? Both?)
  – Put the problem into context (long-term data is needed)
  – Set goals for recovery and restoration to a sustainable state
  – Advise lake managers, set policy, generate applied solutions
  – Evaluate recovery efforts and targets
- ***A foundation of the process for holistic lake management!***

Lake Simcoe Region Conservation Authority

- One of 36 conservation authorities in Ontario
- Watershed-scale management of water and other natural resources in partnership with government, landowners, and other organizations
- Mission: Provide leadership in the restoration and protection of the environmental health and quality of Lake Simcoe and its watershed
- Winner of the 2009 International Thiess River*prize*
  – excellence in watershed management

Lake Simcoe Region Conservation Authority

Logo: LSRCA

Lake Simcoe Protection Act

- Provincial law – effective June 2, 2009
- Watershed-based plan to restore and protect health of Lake Simcoe
- Key objectives:
  – Phosphorus loading target of 44 tonnes / yr (previous target = 67 t/yr)
    ➢ Current loading (2004 – 2007) = 72-78 t/yr (varies with precipitation)
  – Restore hypolimnetic oxygen to 7 mg /L (currently = ~ 5mg/L)
  – Minimum 40% of watershed area natural vegetative cover
    ➢ Current = 35% but highly fragmented (47% is agriculture)
- Main partners: MOE, MNR, LSRCA, local stakeholders

Photo: Google Earth

LSRCA Nearshore Program:

"… research to fill knowledge gaps with aquatic communities including impacts on nearshore water quality…" *(Lake Simcoe Protection Plan)*

- **Key Questions:**
  – How has the nearshore environment changed with human activites?
  – Are biological communities changing? Exotic species?
  – How do species relate to environmental conditions?
  – What data gaps exist in current modeling and monitoring efforts?
  – How are physical conditions changing? Seasonally? Annually?
  – Are our restoration goals realistic? Comparable to pre-disturbance?

Nearshore Zone:

- Lakes have different areas (zones):
  – Shoreline
  – Deepwater (profundal)
  – Nearshore (shallow)
- Nearshore zone is often ignored (data gap) in many lake studies
- Nearshore zone = part of lake that supports warmwater fish communities
  – ~ 10-15°C isotherm
  – Size varies with lake: Erie = large, Superior = small
- Lake Simcoe Nearshore zone = shoreline → 15-20 m depth
- Incorporates many habitats: shoreline, littoral, profundal, tributaries, channels, embayments, offshore shoals

Photo: LSRCA

Nearshore Zone:

Importance of the Nearshore:

- Critical terrestrial – lake linkage
- Important fish feeding / migration / nursery area
- Intense interest by lake users (readily visible)
- Key recreation area (swimming, small boats, aesthetics)
- Area of significant environmental changes:
  - Invasive species (zebra and quagga mussels, plants, etc.)
  - Aquatic plants
  - Shoreline development / hardening

Photo: LSRCA

Nearshore Zone:

Significant environmental challenges:

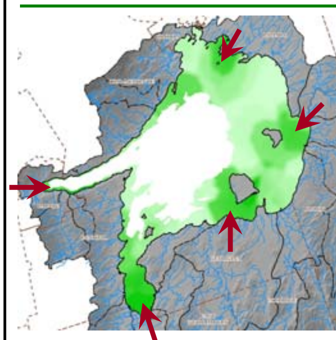
- Nutrient levels (N and P)
- Vegetation (algae, macrophytes)
- Changing communities (zooplankton, benthic invertebrates, fish)
- Pathogenic organisms (*E. coli*, *Cryptospordium*, etc.)
- Land use changes (loss of wetlands, shoreline alteration, etc.)
- Invasive species
- Climate change (altered run-off, water levels, water quantity)

Photo: LSRCA

LSRCA Nearshore Program:

- **Objectives:** Use scientific research to:
  - Build on current research and monitoring
  - Identify emerging environmental issues
  - Support adaptive management of the Lake Simcoe watershed
- **Key research areas:**
  - Monitor physical lake conditions (temperature, light, oxygen, pH, etc.)
  - Sediment nutrients
  - Develop and use organisms to track environmental change
  - Paleolimnology: reconstruct environmental history from lake sediment
  - Use research to generate applied solutions to environmental issues
  - Aquatic plants (#1 complaint from shoreline residents)

1: Aquatic Plants



5 areas of high plant growth

What controls plant community?

- Depth (light!!!)
- Substrate (= exposure?) (suitable – stable - nutrients)
- Phosphorus input (more nutrients = more plants)
- Tributary Size (bigger = more nutrients)

Map: LSRCA

1: Aquatic Plants

Cooks Bay Comparison:

1984-1987	2006	2008
11 species	14 species	13 species
Chara sp. dominant	*Chara* sp. (shallow-north)	*Chara* sp. (shallow-north)
M. spicatum at 5 sites (east side)	*M. spicatum* (shallow-south)	*M. spicatum* (shallow-south)
Utricularia vulgaris (common bladderwort)	*C. demersum* (deep)	*C. demersum* (deep)
Max. depth = 6.0 m	Max. depth = 8.5 m	Max. depth = 10.5 m
Mean wet wt: 1.2 kg/m^2	Mean wet wt: 1.4 kg/m^2	Mean wet wt: 3.1 kg/m^2

More Light / Increasing Plants / More Exotic Species / Growing Deeper

2: Benthic Monitoring

- Use benthic invertebrates to track environmental change
- Animals found on lake bottom: mud, sand, rocks
- Molluscs, worms, crayfish, insect larvae, sponges, etc.
- Most famous (infamous): zebra mussels
- Some species very sensitive to environmental change
- Important for nutrient cycling and as a food source (deepwater fish)

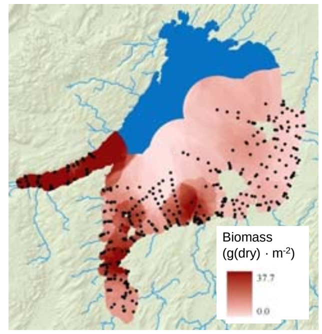
Photo: U. Colorado

2: Benthic Monitoring

Rawson	Kilgour et al.	LSRCA
1926-8 sampling	2005 sampling	2008 sampling
185 taxa	137 taxa	105 taxa
Midge larvae = 50%	Zebra mussels dominant	Zebra mussels dominant
16 bivalve taxa:	**9 bivalve taxa:**	**4 bivalve taxa:**
Pisidium (8 spp.) *Sphaerium* (4 spp.) *Lampsilis* *Anodonta* *Unio*	*Pisidium* (8 spp.) *D. polymorpha* (No quagga mussels but likely in lake)	*Pisidium* (1 spp.) *Musculium* (2 only) *D. polymorpha* *D. rostriformis bugensis*

- Decrease in native clams / mussels (outcompeted by zebra mussels)
- Other changes suggest declining quality in shallow waters

Zebra Mussels 2009-2010



- 747 sites / 43, 952 mussels
- Biomass + population trends
- Limited to <20 m
  - except Kempenfelt Bay
- Quaggas increasing!

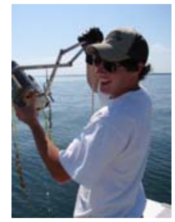


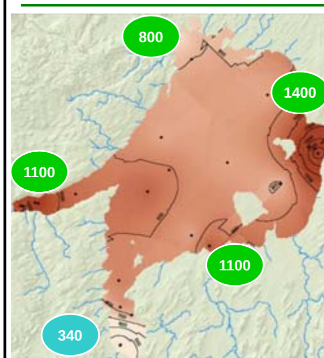
Photo: LSRCA

3: Sediment Nutrients

- Nutrients (e.g. phosphorus) settle to sediments over time
- Can be released into water under low oxygen conditions
- Can be a significant nutrient source
- Also: nutrients pulled inshore by zebra mussels, used by plants, released under low oxygen conditions
- Lake Simcoe Nearshore Program:
  - compare nearshore and offshore sediment nutrients
  - are nutrients available for species?
  - how fast is it accumulating?
  - are nutrients being released? Under what conditions?

Photo: LSRCA

3: Sediment Nutrients

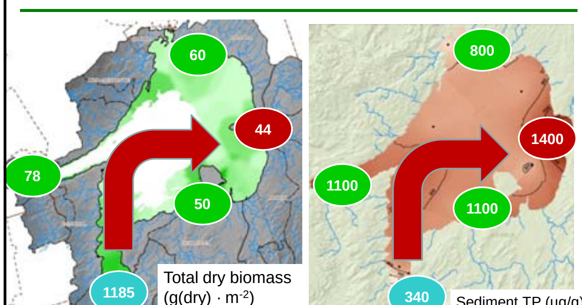


Highest: Beaverton

Lowest: Inner Cook's Bay

- L. Champlain, VT: 500 – 600 µg/g
- L. Winnipeg, MB: ~800 µg/g
- **L. Simcoe, ON: 340 – 1400 µg/g**
- Chesapeake Bay, MD: 400-1500 µg/g
- L. Taihu, China: ~2100 µg/g

3: Plants vs Sediment Nutrients



Low sediment TP = Plant uptake? 75 – 97% P from sediment

High sediment TP = P transport and release with plant death? Experiments!

Map: LSRCA

4: Physical Monitoring

- Measure and compare physical conditions
  - Temperature
  - Acidity
  - Nutrients
  - Oxygen
  - Light levels
- How do these variables change over the year (summer vs winter)
- What effect do these changes have on lake organisms

Photos: LSRCA

5: Paleolimnology

- Study the environmental history of a lake by inferring past limnological conditions using indicators (biological, geo-physical, chemical) archived in sediments.
- Use the past to assess current conditions (put in long-term context) and track environmental changes (use to predict future changes).
  - When did environment changes occur?
  - What is the amount of change from natural variation?
  - What was the environment like in 1950? 1800? 10,000 yr BP?
  - What are realistic recovery targets?

6: Paleolimnology

- Lake Simcoe:
  - track historic deepwater oxygen
  - track changes in phosphorus
  - assess plant and fish populations
- Dissolved Oxygen:
  - Pre-1820: > 7 mg/L
  - 1820 – 90: 3 – 5 mg/L (land clearance)
  - 1960 – 1990: 2 – 3 mg/L (urbanization)
  - Since 2000: ~ 4 – 5 mg/L (P-reduction)
- Phosphorus:
  - Increases with forest clearance
  - Increases with Trent-Severn / Holland Marsh
  - Increases with urbanization
  - Decreases with P-reduction
  - Shows community changes with zebra mussels and climate change
- Plants? Fish? Climate?

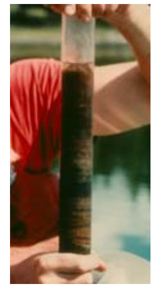


Photo: Smol 2008

Summary

LSRCA Nearshore Monitoring Program:

- Track environmental changes in this critical, previously unstudied, lake zone
- Establish baseline data for future monitoring studies
  - Exotic species introductions? Climate change?
- Tools for tracking changes:
  - Plant, animal, algae communities (how are these changing?)
  - Monitor standard lake health variables
  - Study the past to predict the future
- Evaluate success of recovery targets (effective? realistic?)
- Transfer our knowledge to other lakes and lake users
- Use science as a foundation for sustainable lake management

Partnerships

Government:
- Environment Canada (Science Staff and Lake Simcoe Clean-up Fund)
- Ontario Ministry of Environment
- Ontario Ministry of Natural Resources
- Lake Simcoe Fisheries Assessment Unit

Academic:
- York University
- Queen's University
- Trent University
- University of Toronto
- University of Western Ontario
- University of Waterloo

Also:
- Georgian College
- York Region District School Board
- Local Interest Groups (Lake Simcoe Conservation Foundation)

Acknowledgements

Lake Simcoe Region Conservation Authority

- Lake Simcoe Clean-up Fund
- Field / Lab Assistance (LSRCA): L. Bennett, K. Bolton, R. Bolton, C. Eves, D. Lembcke, S. Lynn, R. MacLean, E. O'Connor, T. Tennant, R. Wilson, G. Yerex
- GIS (LSRCA): D. Campbell, M. Dennis, J. Bennett
- Lake Simcoe Conservation Foundation
- Towns of Georgina and Innisfil
- Environment Canada
- J. Winter, E. Stainsby, J. Young (MOE)
- D. Evans (MNR / Trent U.)
- R. Quinlan, D. Rodé (York U.)
- J. Smol, J. Hawryshyn (Queen's U.)
- J. King (U. Rhode Island)

R/V Ouentironk Photo: LSRCA