# Six decades of Lake Ontario ecological history according to benthos

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# Introduction

## Historic environmental changes in Lake Ontario:

- 1940s - 1970s: **cultural eutrophication** led to water quality deterioration and nuisance algal blooms *(Schelske, 1991)*
- 1980s: the 1972 Great Lakes Water Quality Agreement resulted in controls on phosphorus loadings and **initiated ecosystem recovery** *(Mills et al., 2003)*
  - Lake trout population restoration in 1973
- **Species invasions:**
  - 1989: zebra mussels *(Griffiths et al., 1991)*
  - 1990: quagga mussels *(Mills et al., 1993)*
  - 1998: round goby *(Owens and Dittman, 2003)*

# Historic data

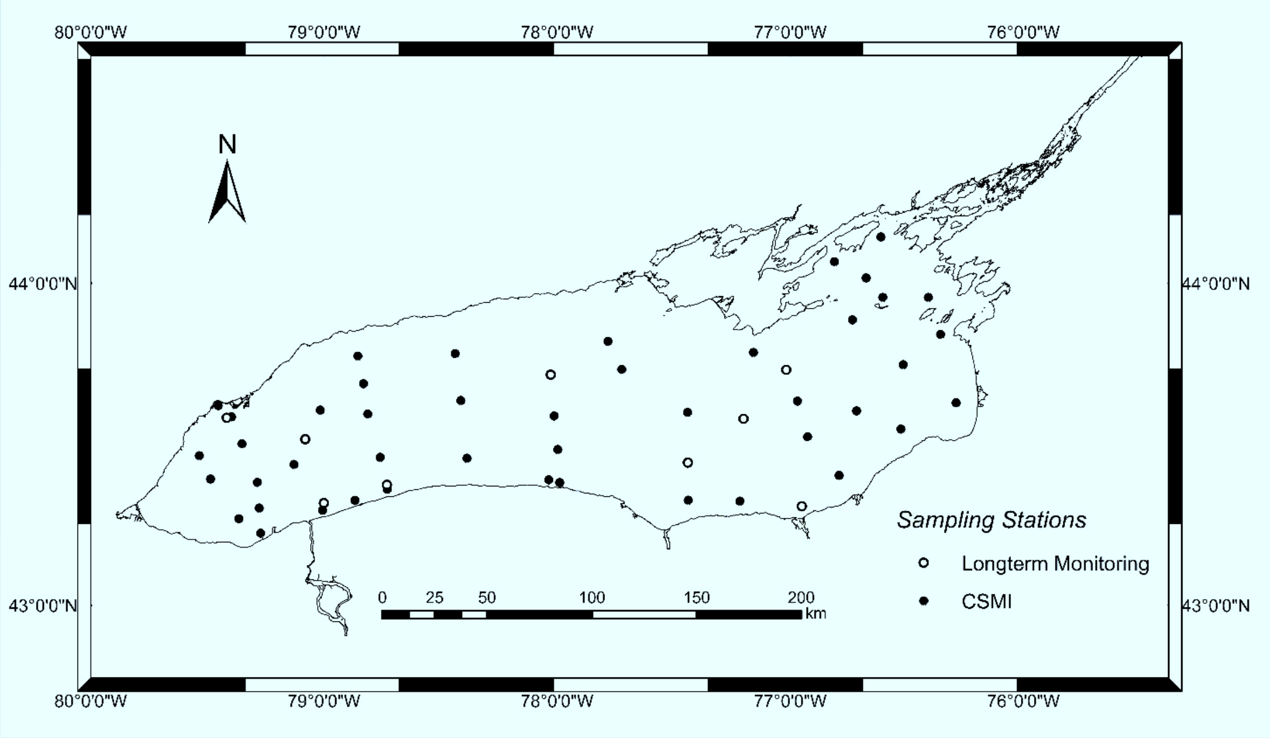
- Benthos of Lake Ontario has been studied intensively, particularly in the last six decades *(Mozley, 1990; Nalepa, 1991)*
  - the first benthic samples were collected in **1872** *(Nicholson, 1873)*
  - the first large systematic survey was conducted in **1964** *(Hiltunen, 1969)*
- **13** lake-wide benthic surveys were conducted in Lake Ontario from 1964 to 2018
- For **11** of them we were able to acquire species-level data

# Questions:

- Can we track the effect of the 1972' Great Lakes Water Quality Agreement actions on benthic community?
- Zebra mussels have positive effects on abundance of littoral benthic species in small lakes. Did we see these effects in Lake Ontario?
- What effects quagga mussels have on benthic invertebrates both nearshore and offshore?
- Zebra *vs* Quagga effects: similar or not?
- How Round goby predation effect dreissenids?

# Methods: 2018' survey

- Samples were collected from **55** stations aboard U.S. EPA R/V *Lake Guardian*
- **Ponar** (0.0523 $m^2$) & 500-µm net
- Survey included most of the stations previously sampled in 1990 - 2013
- Environmental parameters:
  - Parameters of water were measured using a CTD probe and Rosette sensors
  - Sediment nutrients (total phosphorus, organic carbon, and total nitrogen)
  - Surface chlorophyll concentration derived from MODIS satellite (B. Lesht, GDIT)



# Methods: Historic data

| Sampling time | # stations | Sampler | Mesh size, µm | Taxonomic resolution | Author |
|---|---|---|---|---|---|
| **1964, Sep** | 24 | Smith-McIntyre | 600 | Species | *Hiltunen, 1969* |
| **1972, Nov** | 55 | Ponar | 600 | Species | *Nalepa and Thomas, 1976* |
| **1977, Sep** | 151 | Shipek | 150 | Groups* | *Golini, 1979* |
| **1990, Oct** | 25 | Ponar | 600 | Species | *Dermott and Geminiuc, 2003* |
| **1994, Aug** | 51 | Ponar | 500 | Species (excluding *Dreissena*) | *Lozano et al., 2001, Watkins et al., 2007* |
| **1995, Oct** | 41 | Ponar | 600 | Species | *Dermott and Geminiuc, 2003* |
| **1997, Sep** | 68 | Ponar | 500 | Species | *Lozano et al., 2001* |
| **1998, Sep** | 114 | Ponar | 500 | Species | *Watkins et al., 2007* |
| **1999, Aug** | 67 | Ponar | 500 | Species | *Watkins et al., 2007* |
| **2003, Aug - Oct** | 36 | Ponar | 500 | *Diporeia, Dreissena* | *Watkins et al., 2007* |
| **2008, Aug-Sep; 2009, Sep** | 51 | Ponar | 500 | Species | *Birkett et al., 2015* |
| **2013, Jul, Aug** | 45 | Ponar | 500 | Species | *Nalepa and Baldridge, 2016* |
| **2018, Aug, Sep** | 55 | Ponar | 500 | Species | *Our data* |

# How to combine results from different surveys???

- Benthos grabs:
  - Ponar and Smith-McIntyre grabs are similar *(Sly and Christie, 1992)*
  - Converted Shipek densities *(Golini, 1979)* to Ponar equivalents using taxa-specific sampling efficiency conversions *(Sly and Christie, 1992)*
- Species with rare occurrences were pooled into higher taxonomic units
- Used both data by species (11 years) and groups (13 years)
- Calculated average benthos densities by lake zone
  (0 - 30 m, >30 – 50 m, >50 – 90 m, and > 90 m)
- Calculated depth-weighted lake-wide density for each year

# Statistics

- Environmental parameters were analyzed using **P**rincipal **C**omponent **A**nalysis (R version 3.6.1)
- Community structure - using **N**on-metric **M**ulti-**D**imensional **S**caling on species density (R)
- Differences in community composition with Analysis of Similarities (**ANOSIM**, Primer 7)
- used **BEST** analysis to select environmental variables that explain benthic community patterns (Primer 7)
- used “Similarity Percentage” (**SIMPER**) analysis to examine the contribution of each species to the average BC similarity among communities (Primer 7)
- examined changes in overall benthic community structure by major taxonomic groups with NMDS, perMANOVA, and permutational ANOVAs (R)

# Major species and taxa:

Deep-water amphipoda
*Diporeia*

**Oligochaeta**:

- tolerant to organic matter Tubificidae
- intolerant Lumbriculidae

Fingernail clams
Sphaeriidae

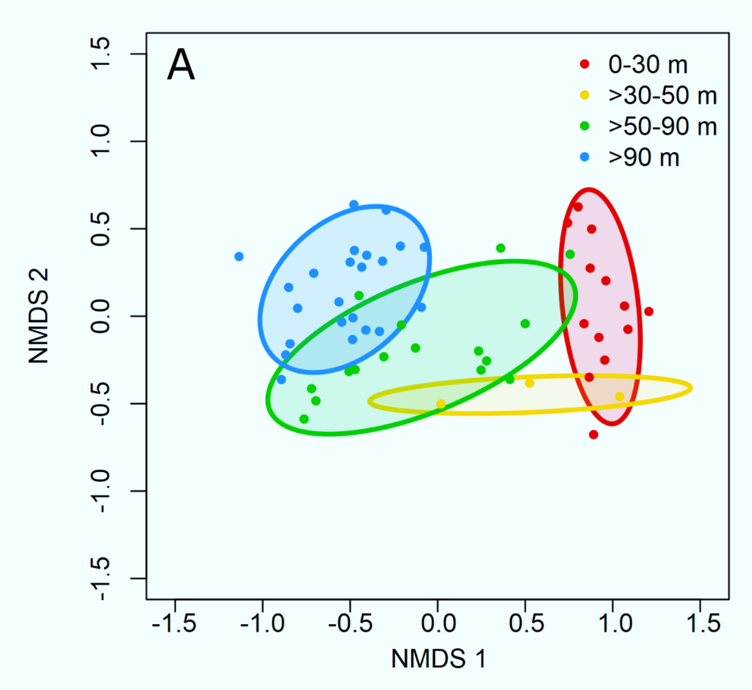
Zebra mussels

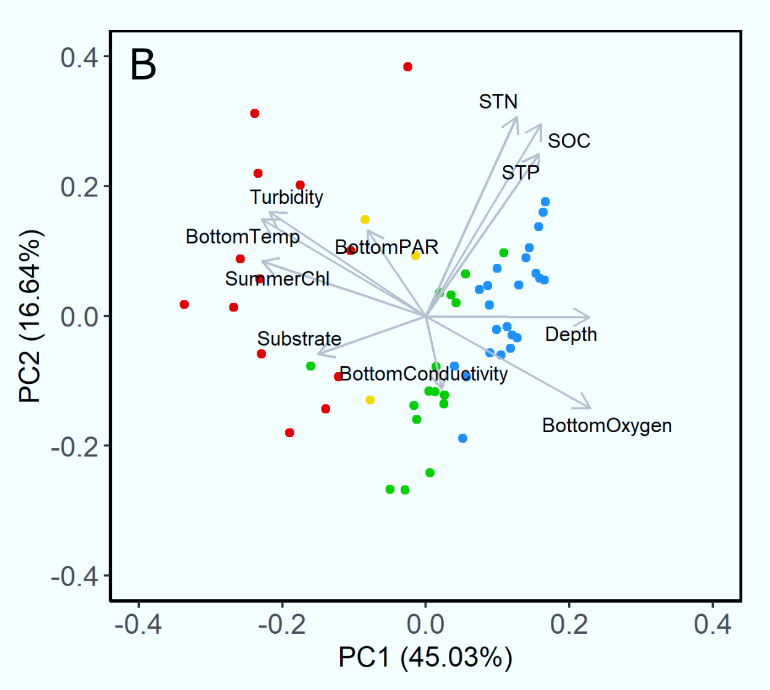
Quagga mussels

Midge larvae
Chironomidae

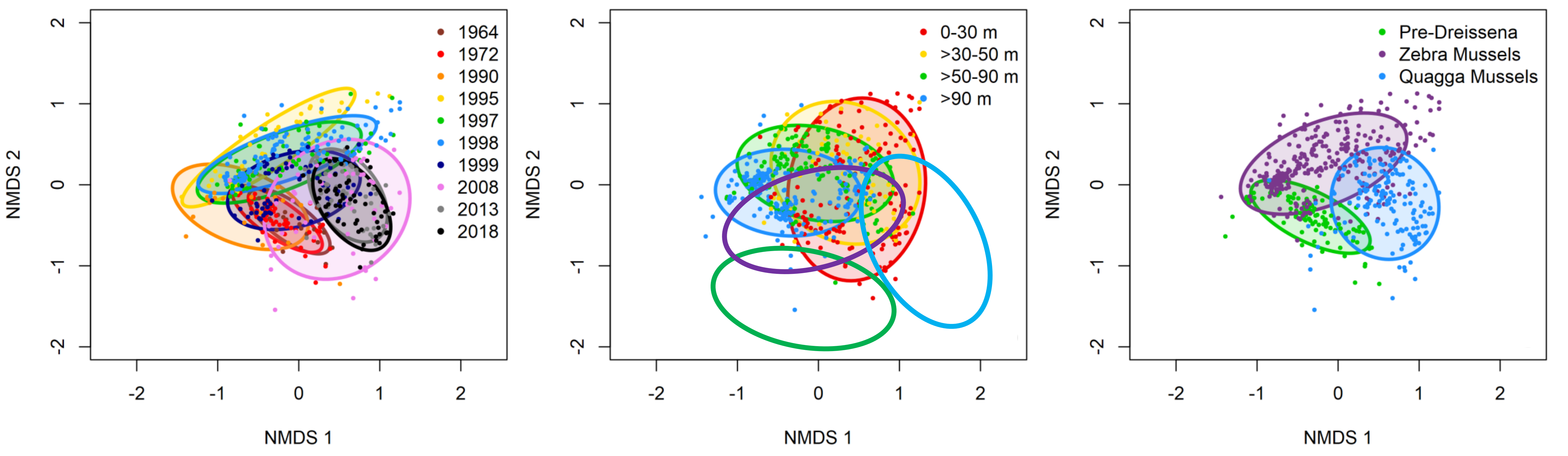
# Results: 2018

- Diversity: **76** benthic invertebrate taxa
  - Oligochaeta (**33** species and higher taxa)
  - Chironomidae (**28**)
  - Malacostraca (**6**), Bivalvia (**3**)
- Density:
  - **67**% *Dreissena r. bugensis*
  - **28**% Oligochaeta
  - **5**% Chironomidae
- Wet biomass: **99.7**% *D. r. bugensis*
- Communities differed by depth zone *(P <0.001, one-way ANOSIM)*
- Highest density and diversity was found at <30 m depth
- Depth, bottom turbidity, and surface chlorophyll best described benthic community structure *(Spearman ρ = 0.756, BEST).*



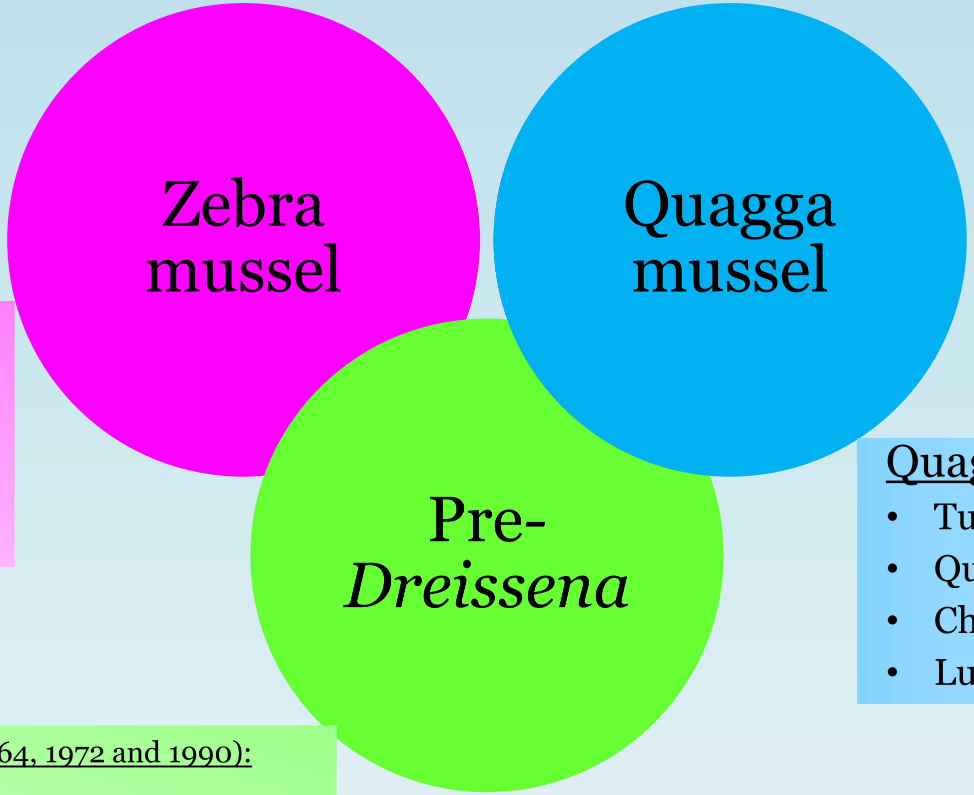
# Long-term changes




Communities differed by:

- depth zone *(R = 0.541, P =0.001, 0 ANOSIM)*
- years *(R = 0.499, P =0.001, ANOSIM)*
- *Dreissena* periods *(R = 0.606, P =0.001, ANOSIM)*

# Three different periods!!




*Zebra mussel* (1995-1999):

- Tubificidae (22%)
- Lumbriculidae (18%)
- Sphaeriidae (18%)
- *Diporeia* (12%)

Quagga mussel (2008-2018):

- Tubificidae (28%)
- Quagga mussel (27%)
- Chironomidae (21%)
- Lumbriculidae (17%)

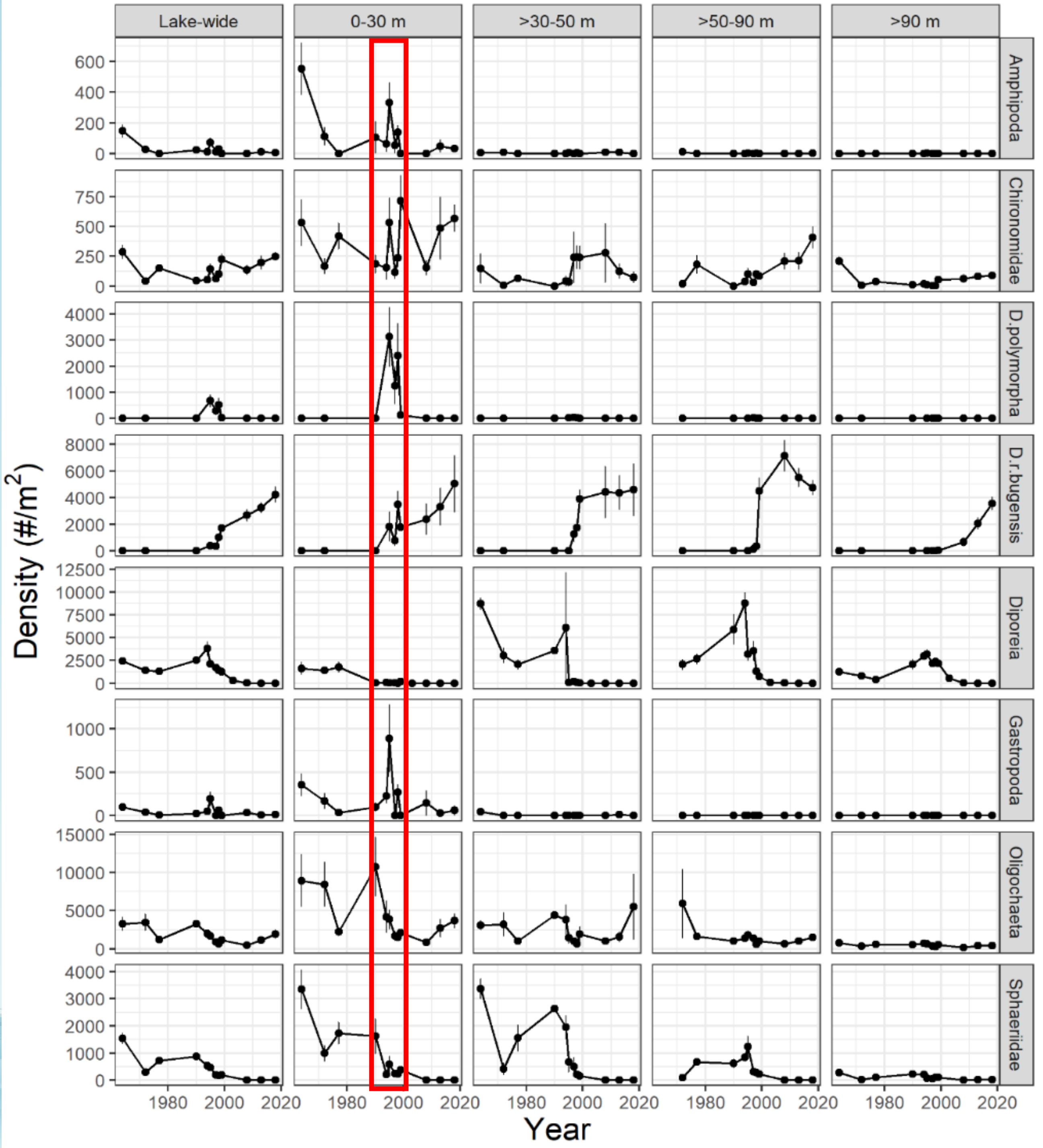
Pre-early *Dreissena* (1964, 1972 and 1990):

- *Diporeia* (23%)
- Tubificidae (21%)
- Sphaeriidae (17%)
- Lumbriculidae (16%)

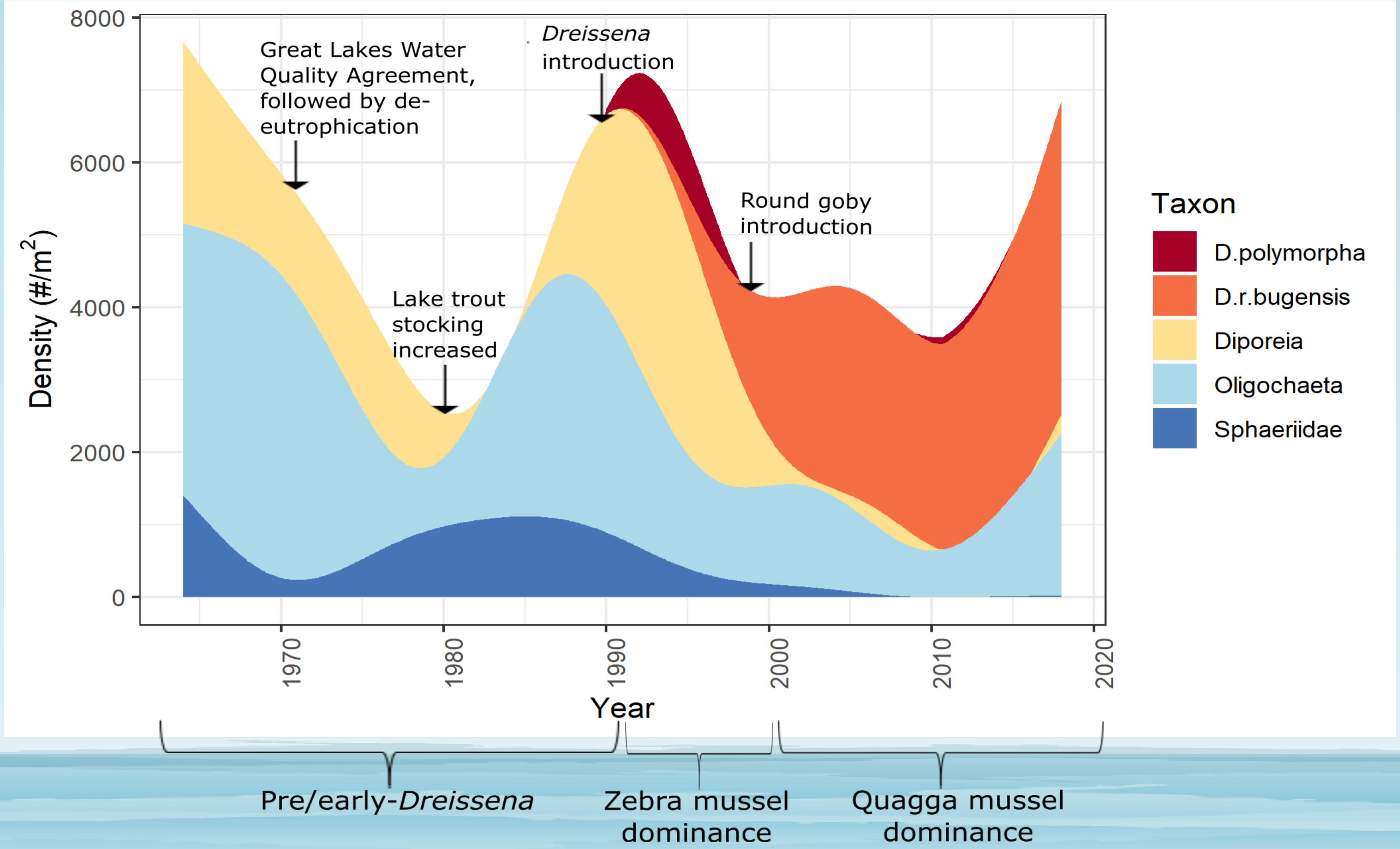
*the most contributing species to community similarity (% contribution)*

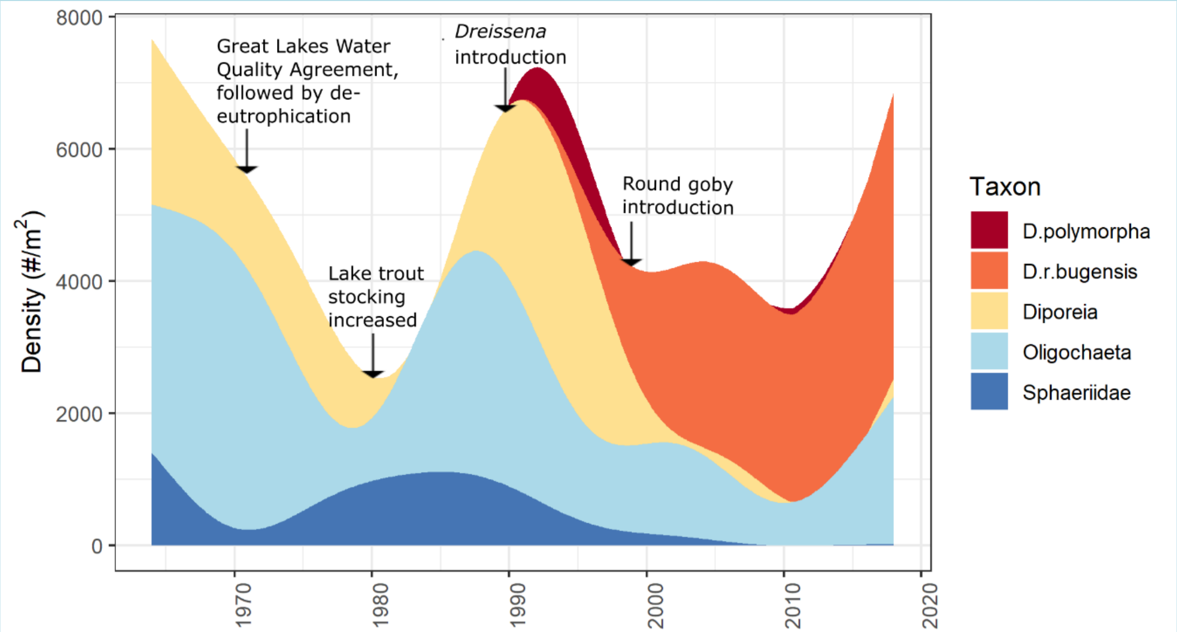
# Zebra mussel effect:

- 1990-1999
- mainly in littoral zone (0-30 m)
- Positively affected:
  - ✓ Amphipoda
  - ✓ Chironomidae
  - ✓ Gastropoda
  - ✓ Oligochaeta: Naididae



# Dynamics of major taxa






# What have we learned?

| Decade | Factor | Effect on benthos |
|---|---|---|
| 1960s | Eutrophication ✓ | High abundance of Oligochaeta and Sphaeriidae |
| Late 1970s | Phosphorus control measures ✓ | decline in Oligochaeta and Sphaeriidae |
| 1980s | Lake trout restoration ✓ | increase in *Diporeia* - predation release? *(Barton and Anholt, 1997)* |
| 1990s | Zebra mussel introduction ✓ | increase in littoral benthos, no much effects on *Diporeia* |
| 2000s | Quagga mussel dominance ✓ | decline in *Diporeia*, increase in Oligochaeta |

# Conclusions?

- ✓Benthic community is a good indicator of long-term environmental changes
- ✓Historic data are important, need to be preserved and analyzed!

# Acknowledgements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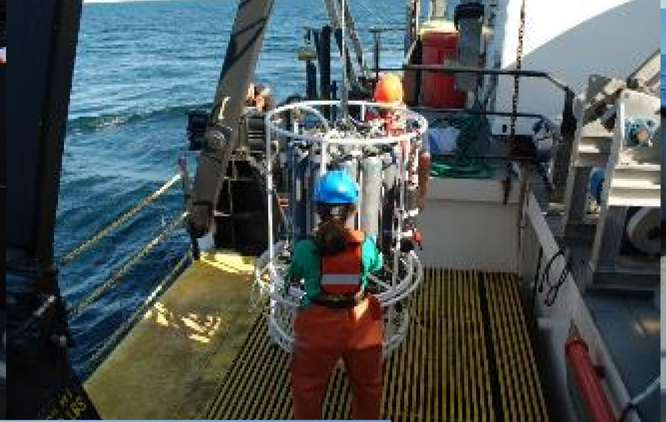
- **Great Lakes Center** staff and students


**Thank you for your attention!!**