Six decades of Lake Ontario ecological history according to benthos

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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)*

Questions:

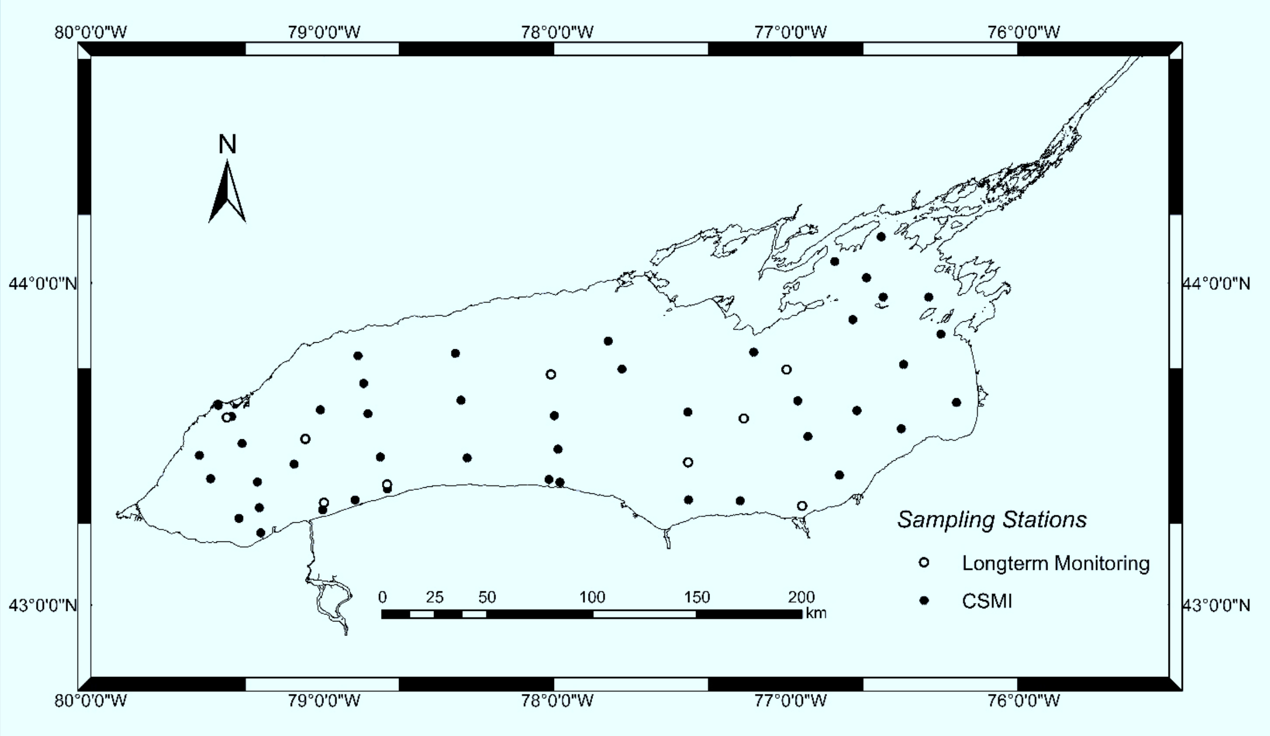
- Can we track the effect of the 1972 Great Lakes Water Quality Agreement actions on benthic community?
- Zebra mussels have positive effects on abundance of littoral benthic species in small lakes. Did we see these effects in Lake Ontario?
- What effects quagga mussels have on benthic invertebrates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

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

Methods: 2018 survey

- Samples were collected from **55** stations aboard U.S. EPA R/V *Lake Guardian*
- **Ponar** (0.0523 m²) & 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	Bottom Grab	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*

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Density data for Lake Ontario benthic invertebrate assemblages from 1964 to 2018

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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

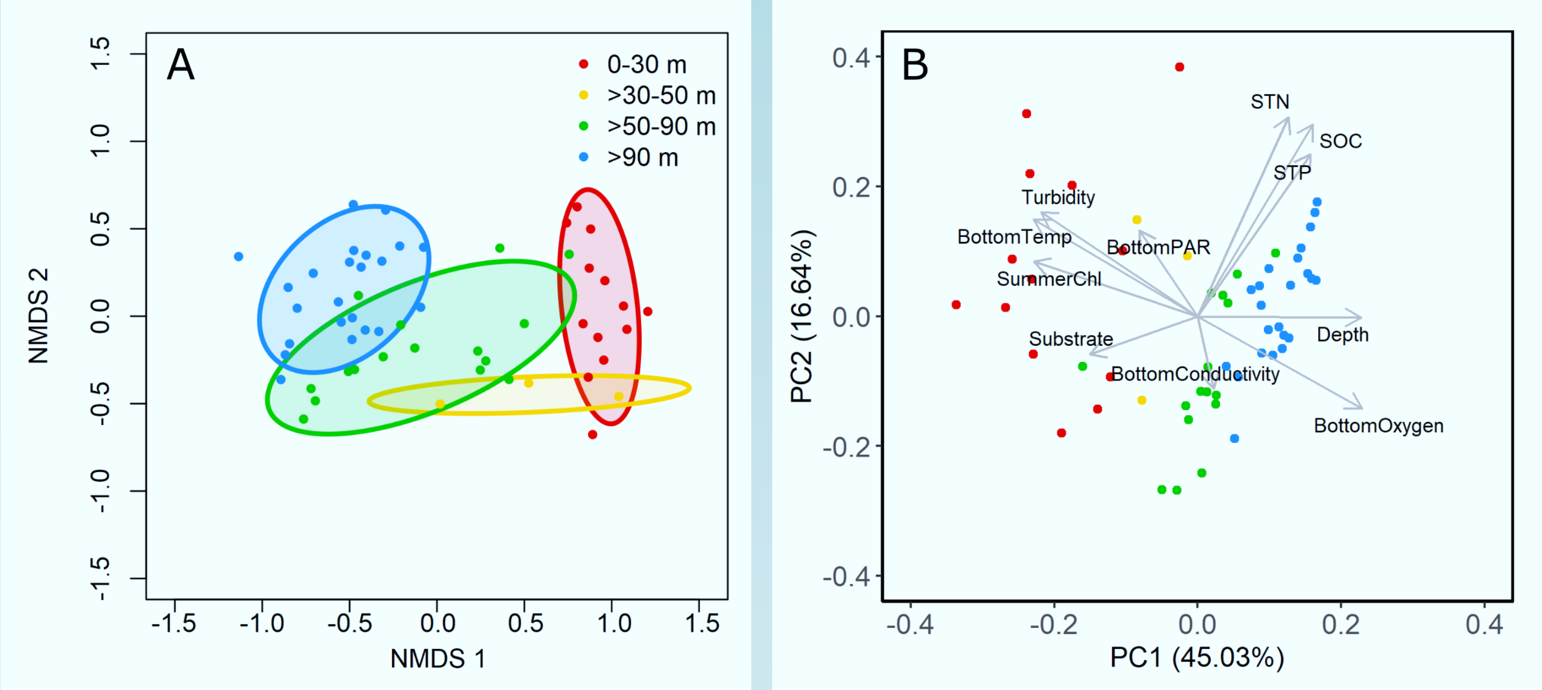
Fingernail clams
Sphaeriidae

Zebra mussels

Quagga mussels

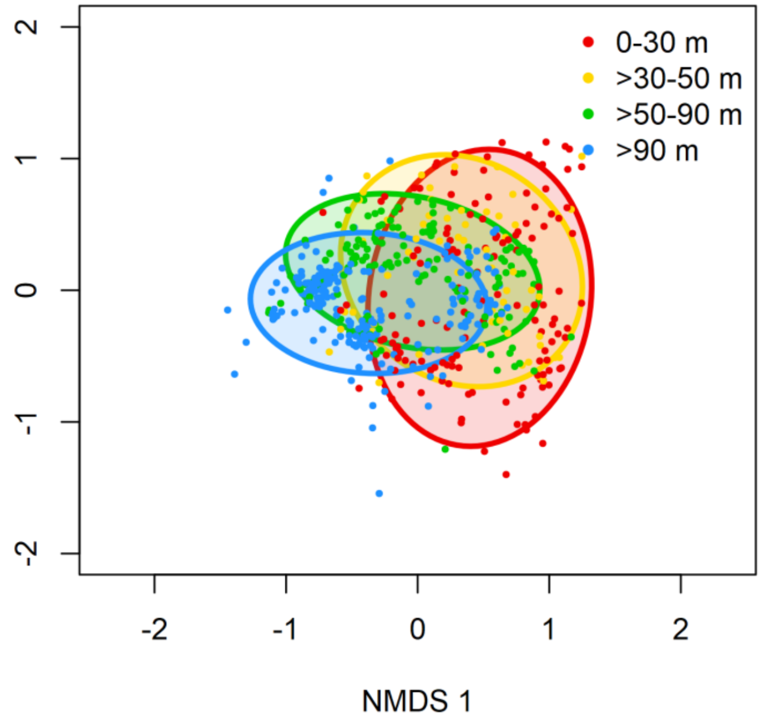
Midge larvae
Chironomidae

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).*

Results: Long-term changes



Communities differed by:

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

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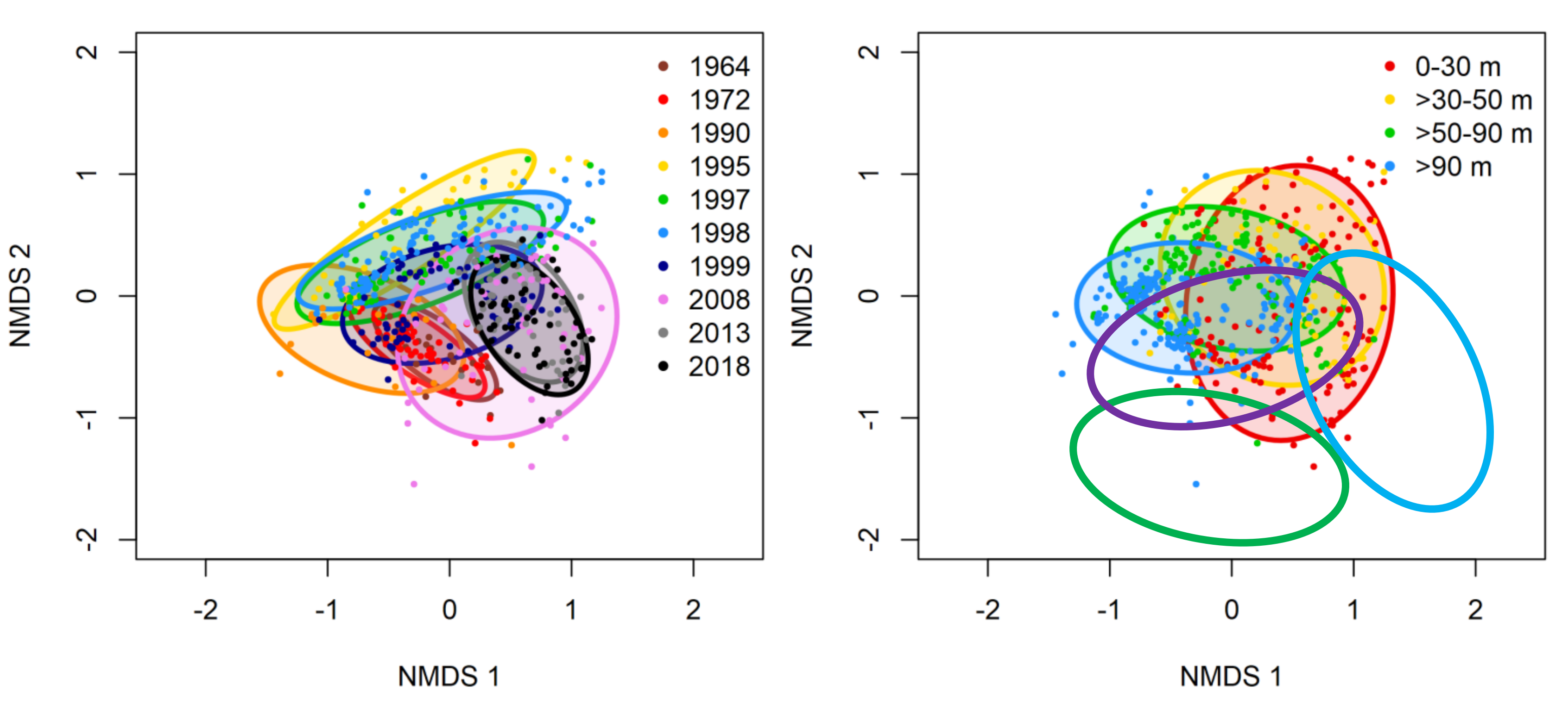

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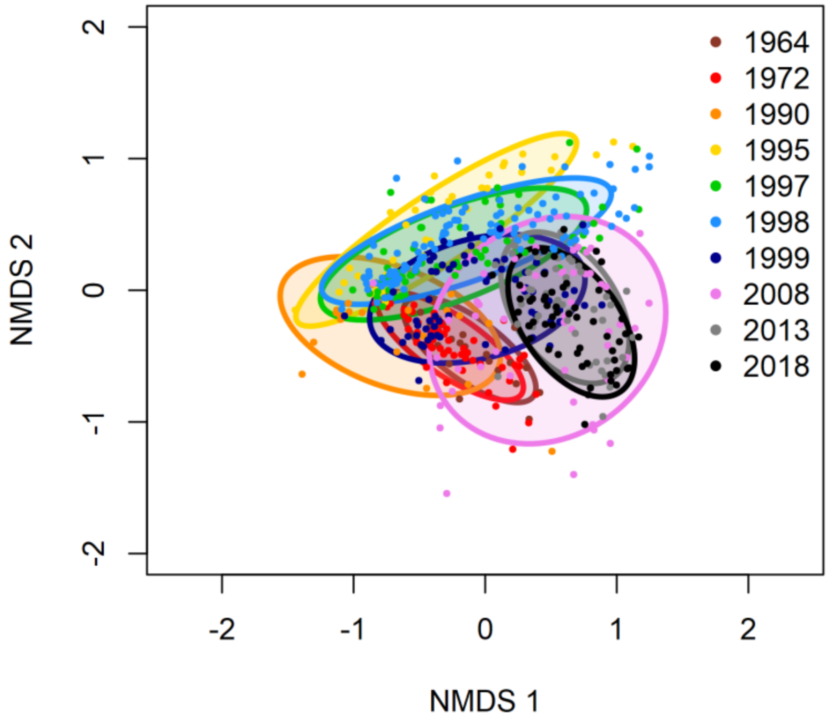

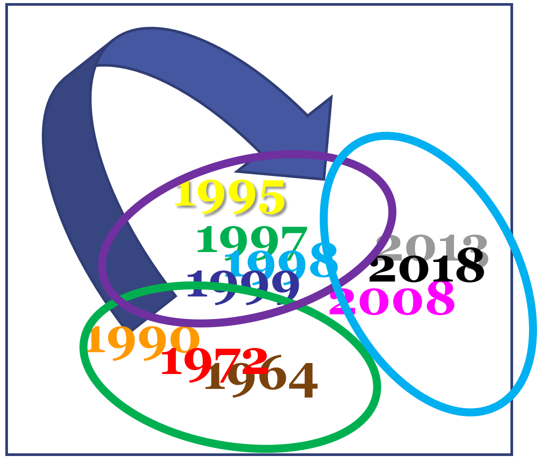

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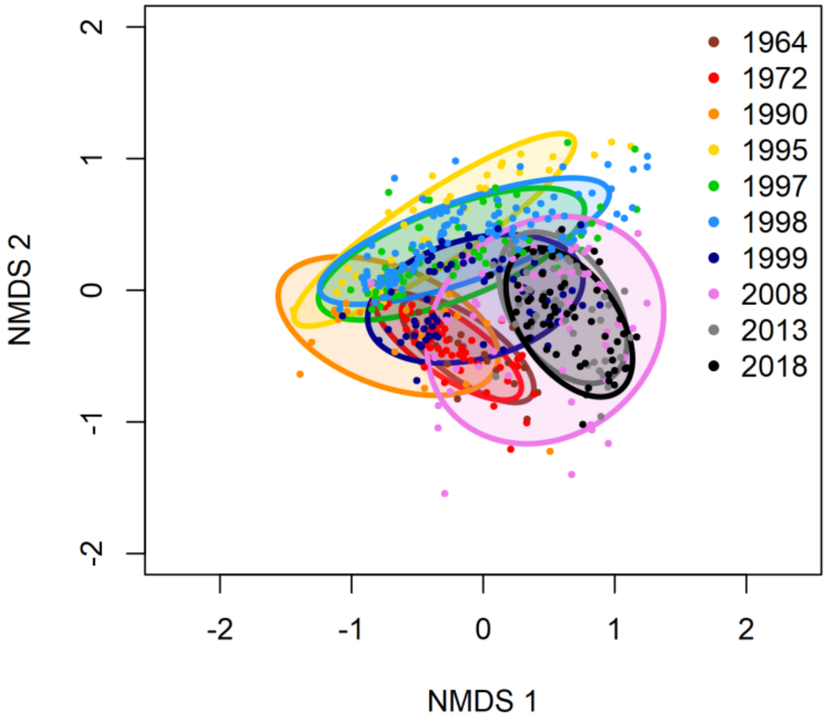

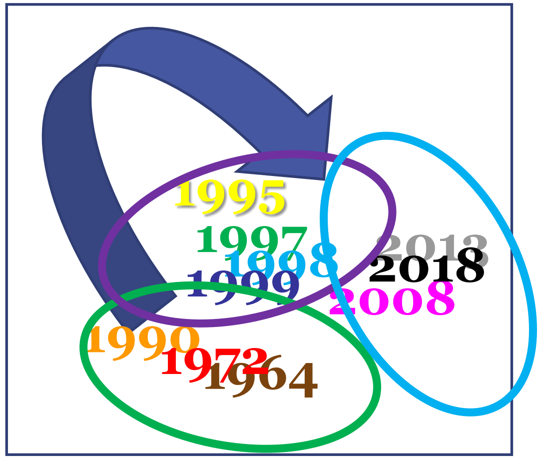

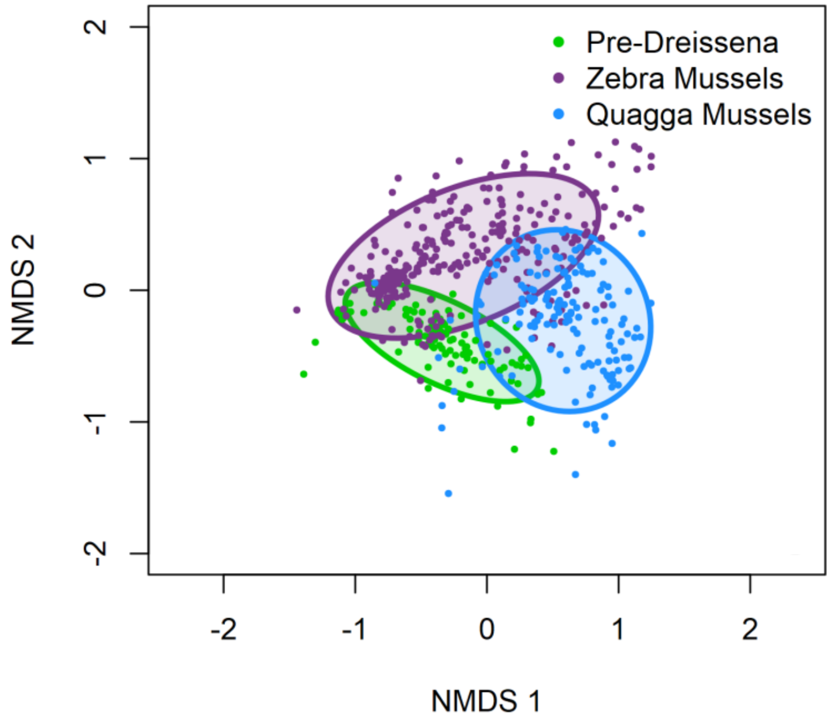

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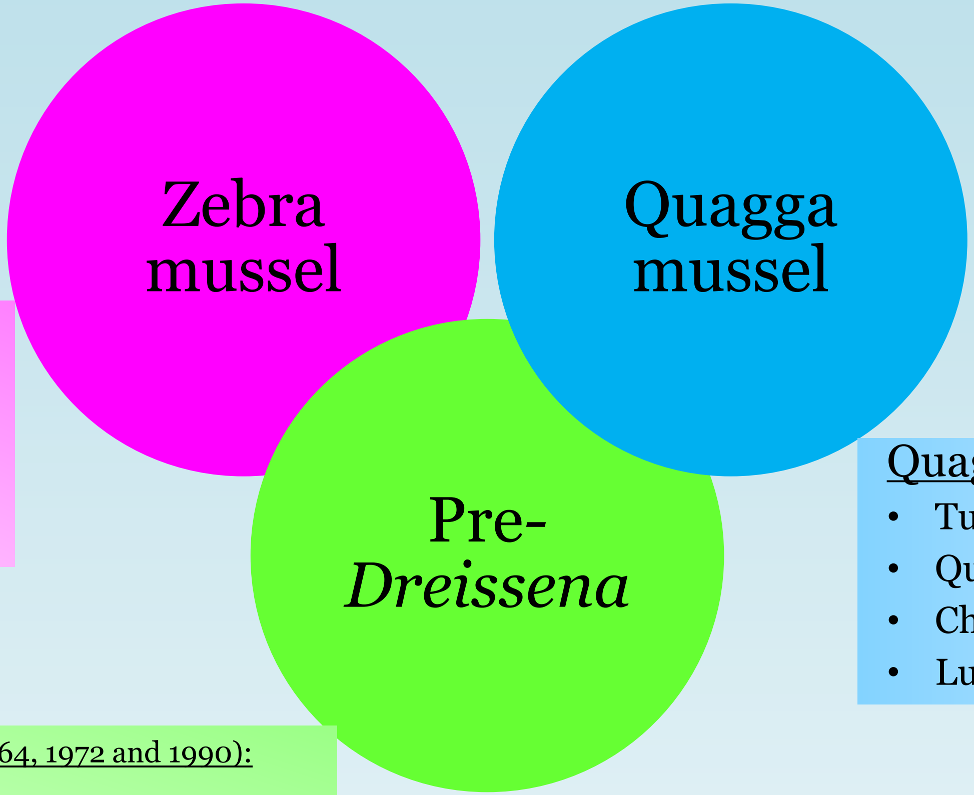
Three different periods!!



<u>*Zebra mussel* (1995-1999):</u>

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

<u>Quagga mussel (2008-2018):</u>

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

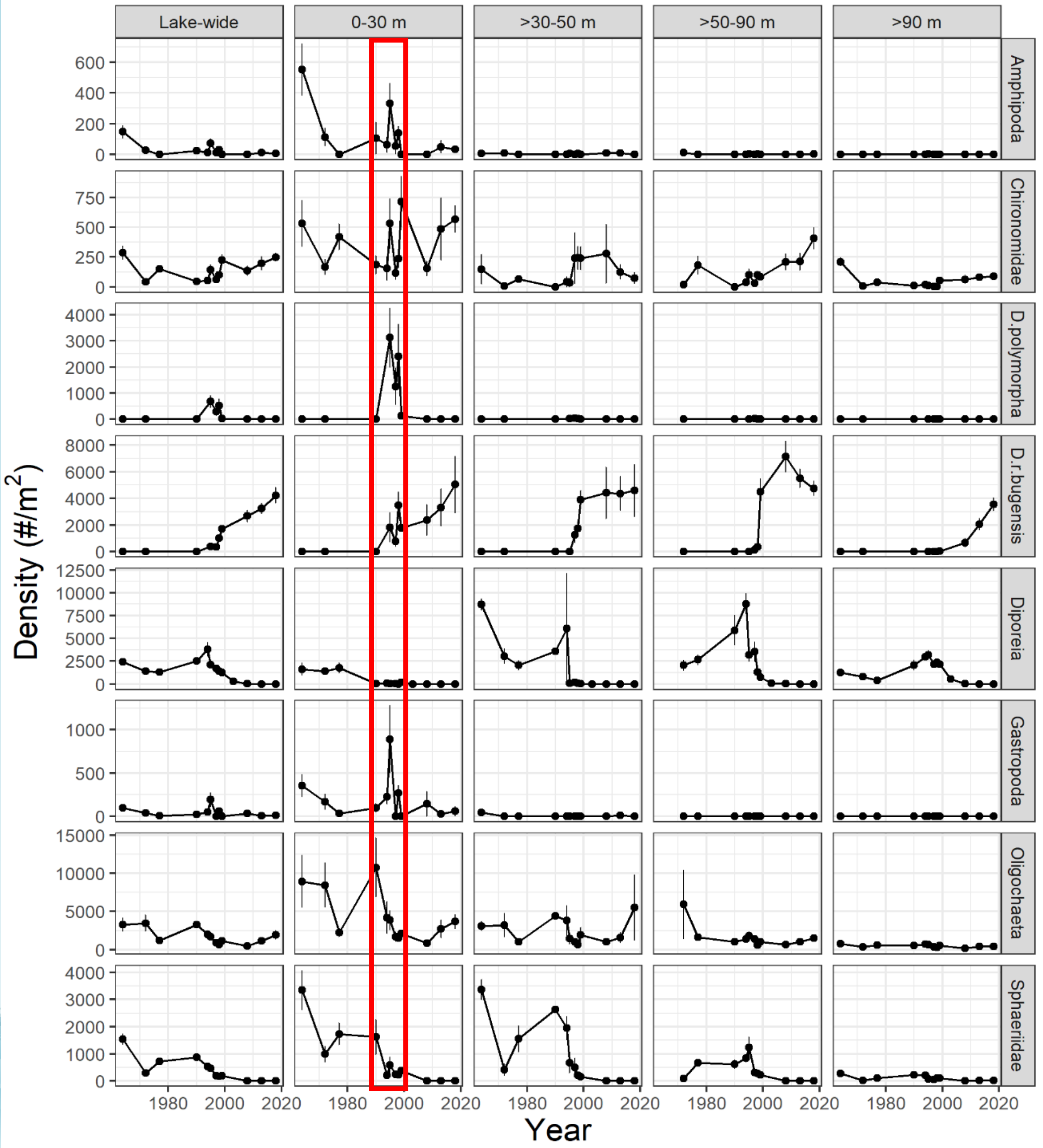
<u>Pre-early *Dreissena* (1964, 1972 and 1990):</u>

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

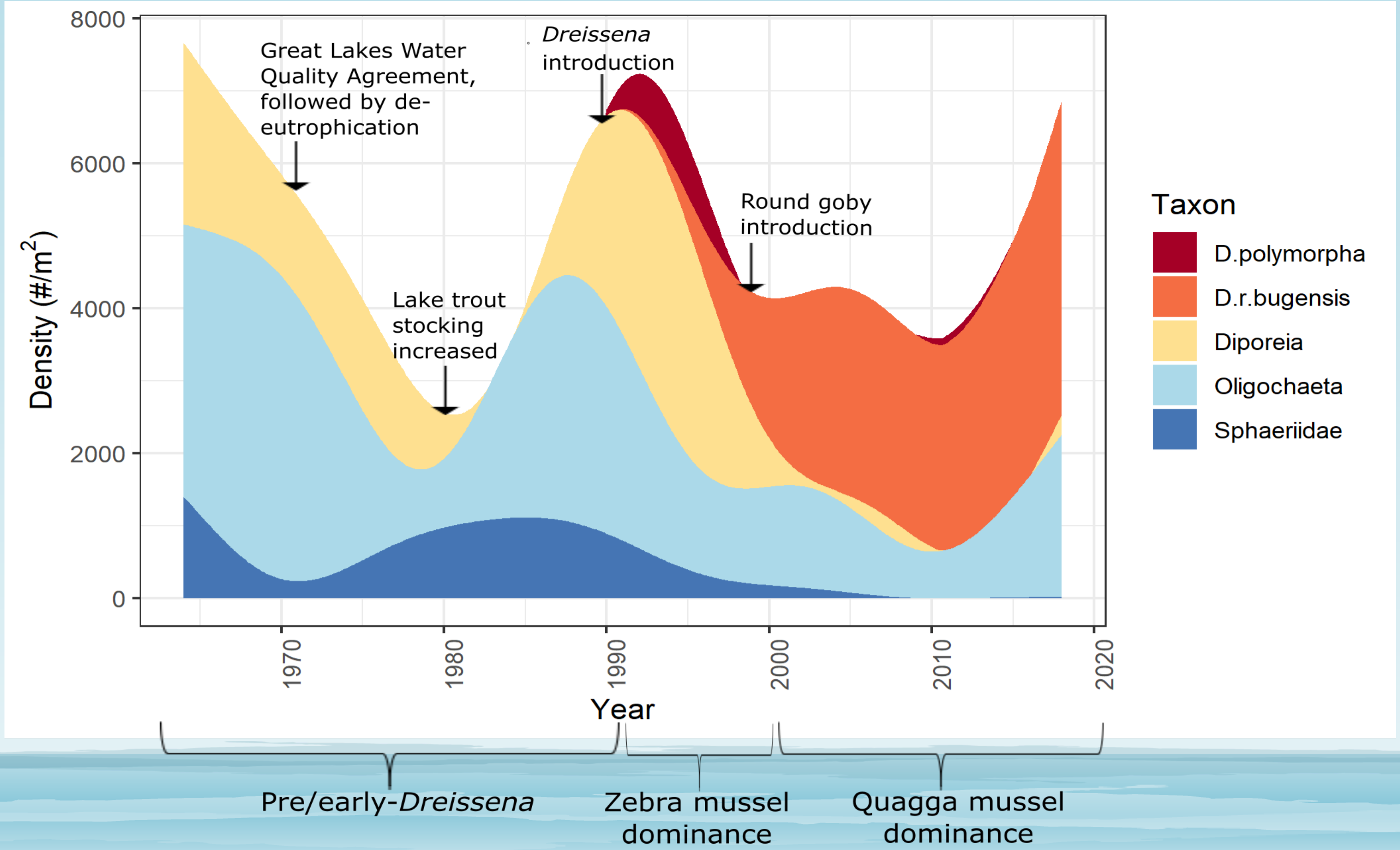
the most contributing species to community similarity (% contribution)

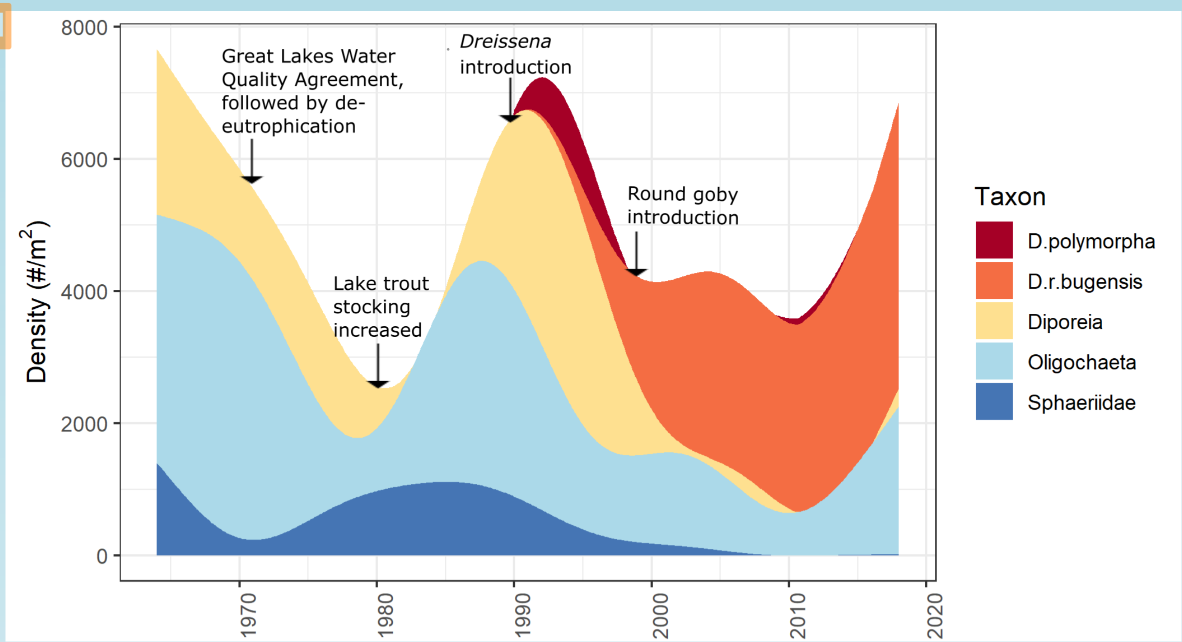
Zebra mussel effect:

- 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
- ✓Zebra and quagga mussels seems to have different effect on benthic community
- ✓No large effect of round goby predation on quagga mussel population was detected
- ✓Historic data are important, need to be preserved and analyzed!

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Thank you for your attention!!