Biomonitoring Using Invasive Species in a Large Lake: *Dreissena* Distribution Maps Hypoxia Zones

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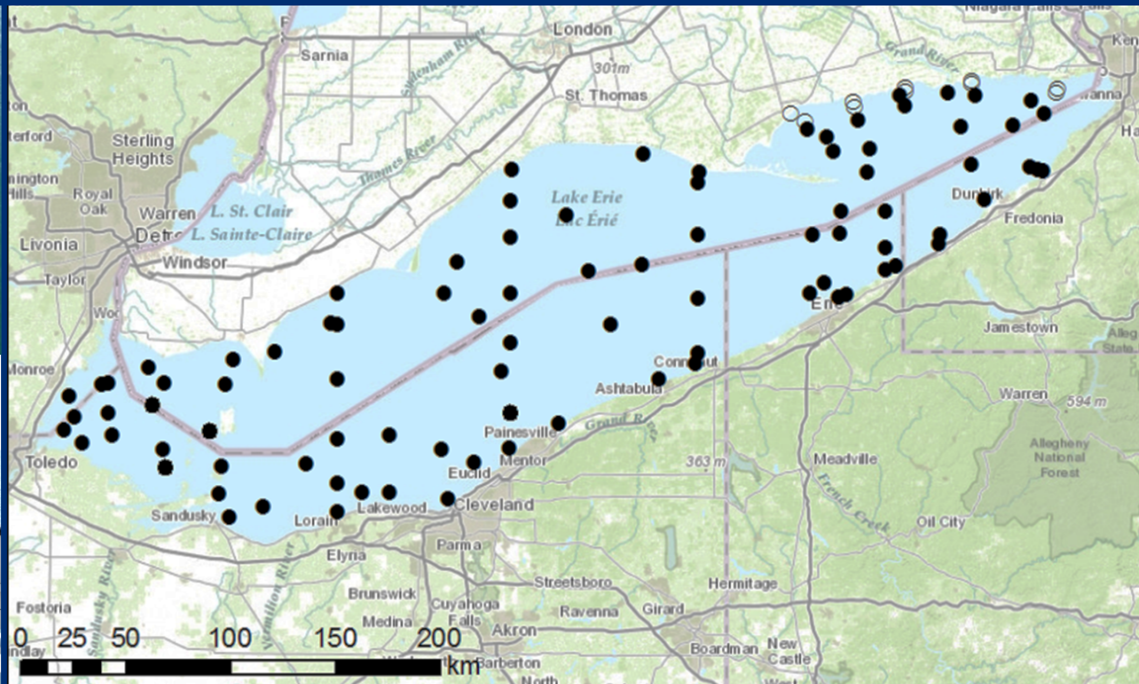
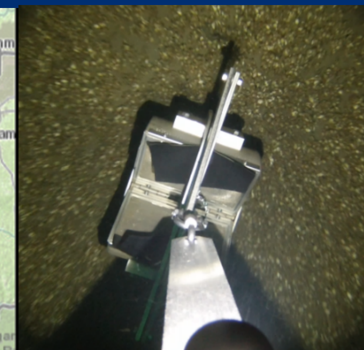
Buffalo State

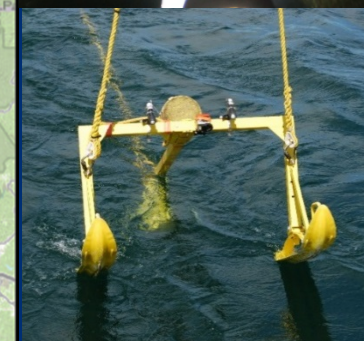
Great Lakes Center

★ 1966–2016 ★

2014 Lake Erie *Dreissena* sampling: 107 sites



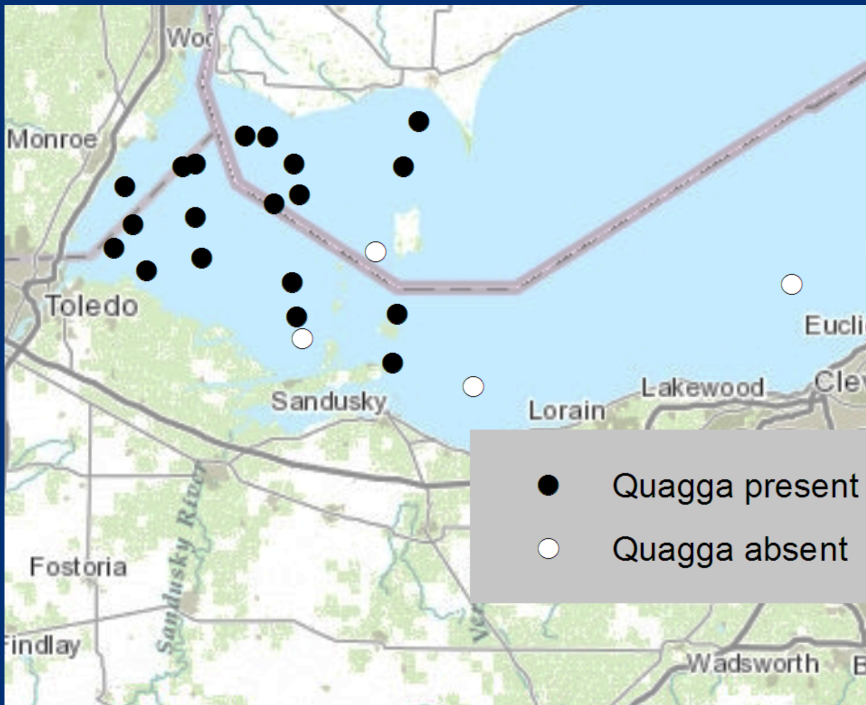


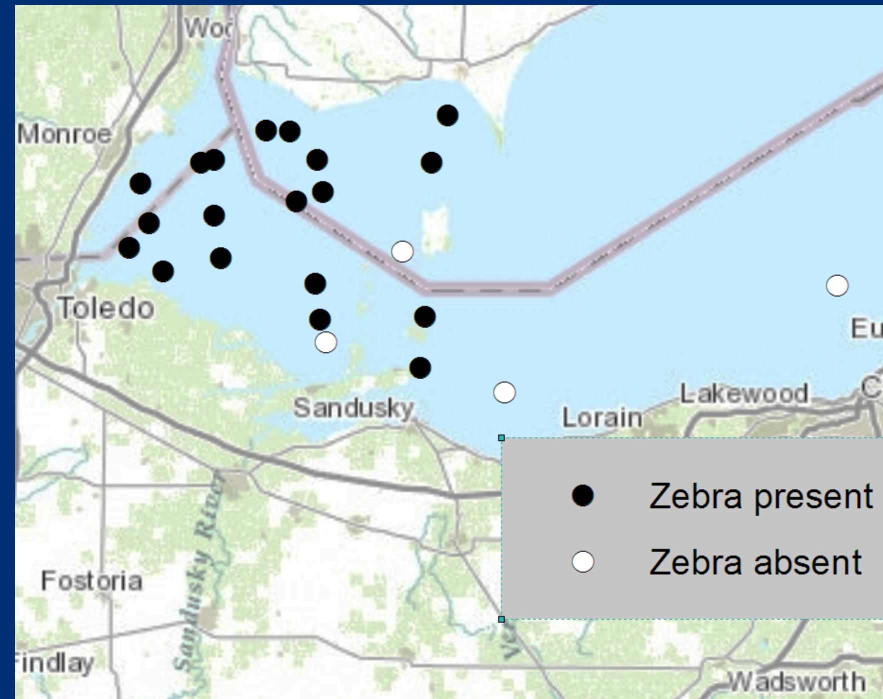


Sampling sites for Ponar (black circles) or SCUBA (open circles)

Sampling method	Western	Central	Eastern	Total
SCUBA diving	0	0	24	24
PONAar grab	66	126	106	298
Video on Ponar grab	57	119	107	283

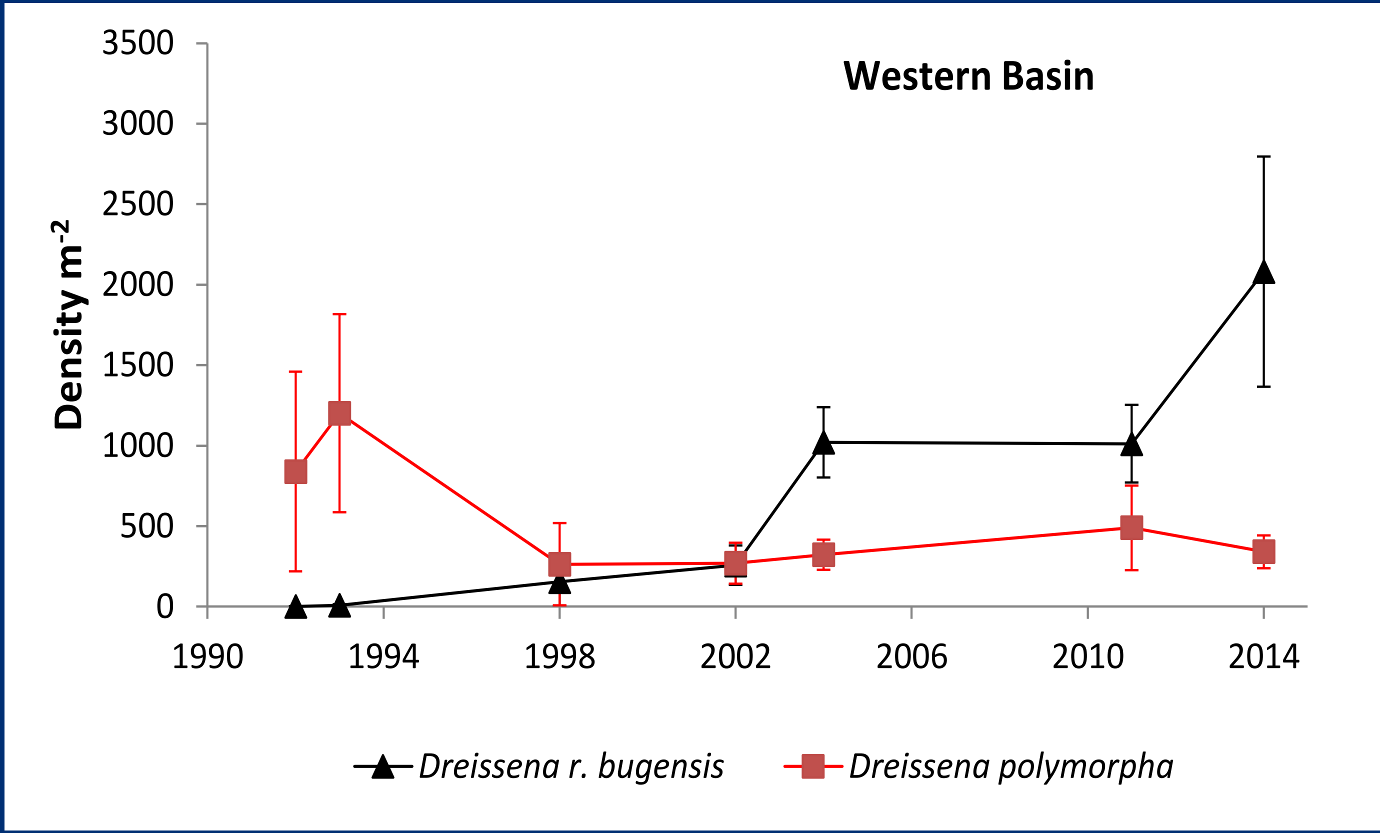
Lake Erie western basin 2014





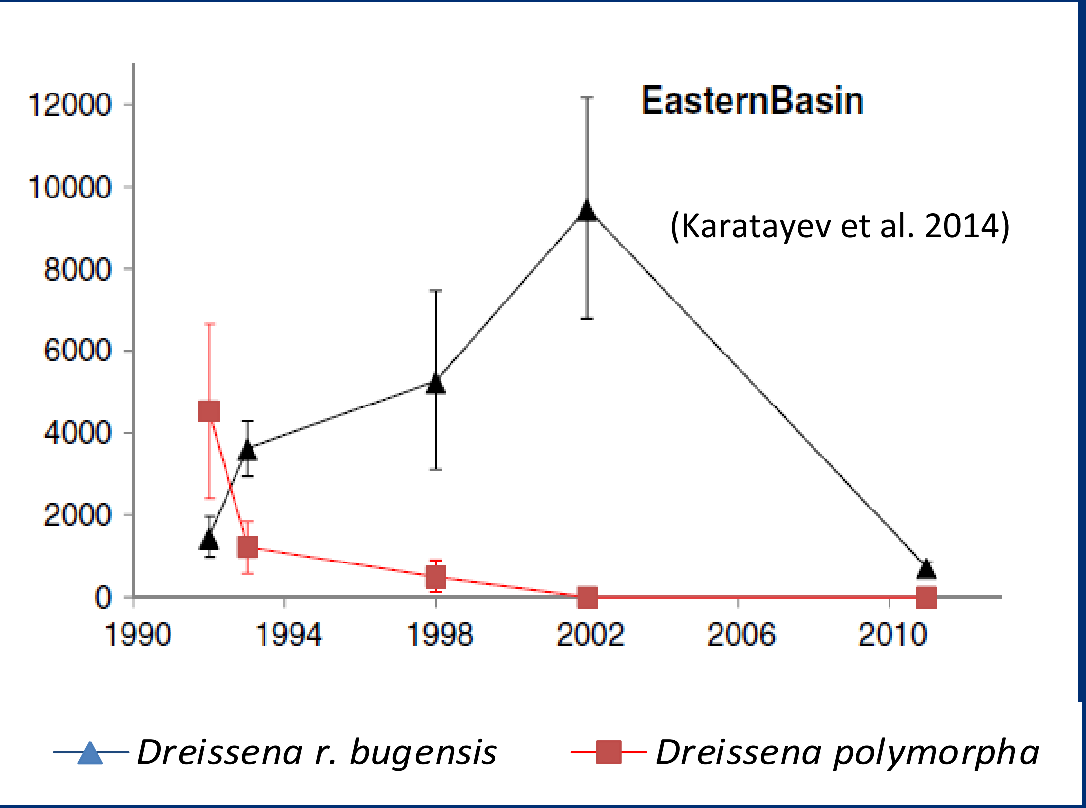
- In 2014 zebra mussels were still common in western basin only, where their occurrences were only slightly lower than that of quagga mussels (91% vs. 86% quagga and zebra mussels respectively)

Western basin (long-term dynamics)



- After the initial pick, zebra mussels density declined and was stable since 1998
- In contrast, quagga mussel density was constantly increasing and reached maximum in 2014

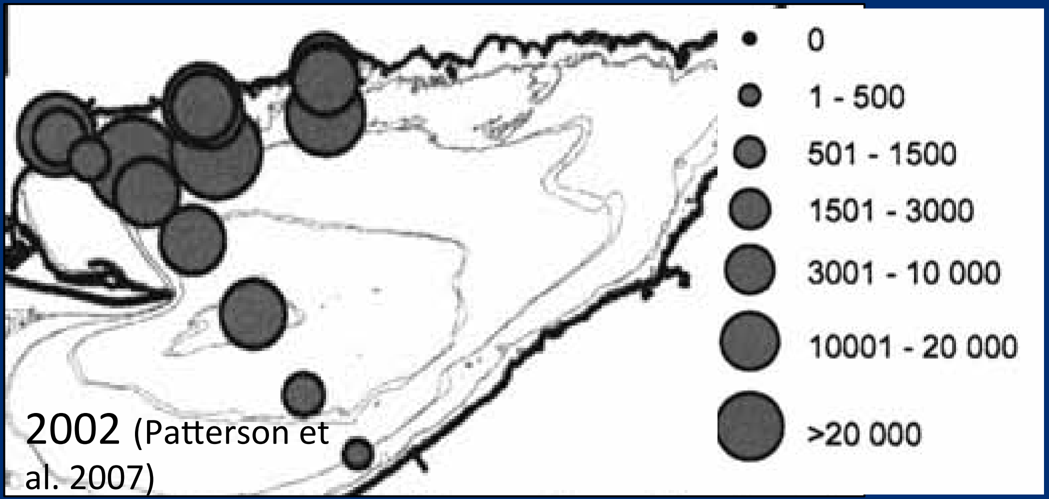
Dreissena spp. density (Eastern Basin)



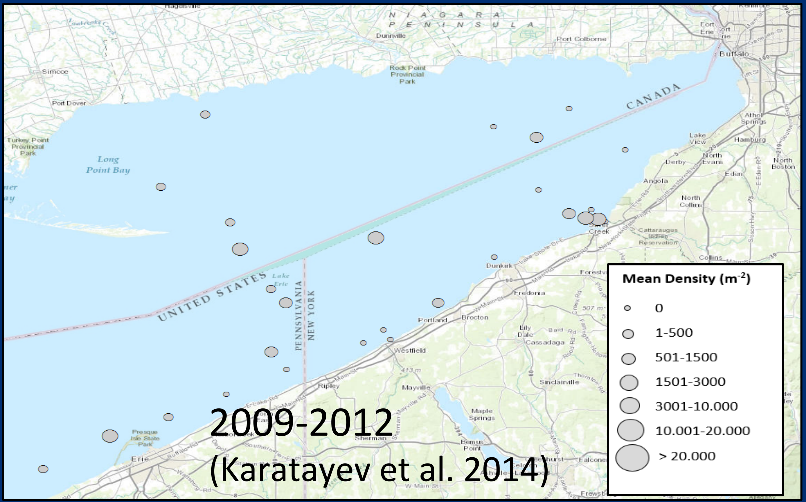
- Basin-wide *Dreissena* spp. density declined **> 12 fold** from **9,481** in 2002 to **742** in 2009-2012
- **Population dynamics or sample bias?**

Dreissena density (Eastern Basin)

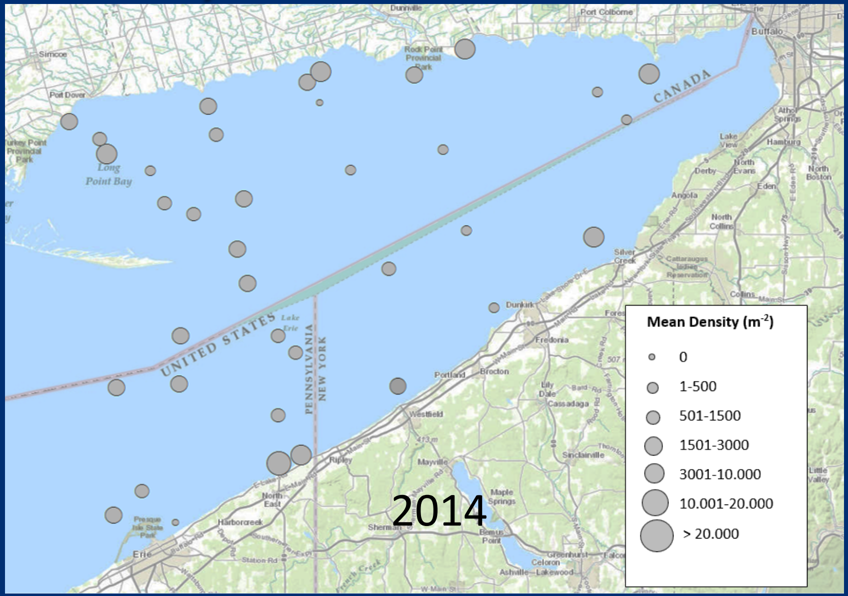
9,481 ± 11,173 m². Overestimation?

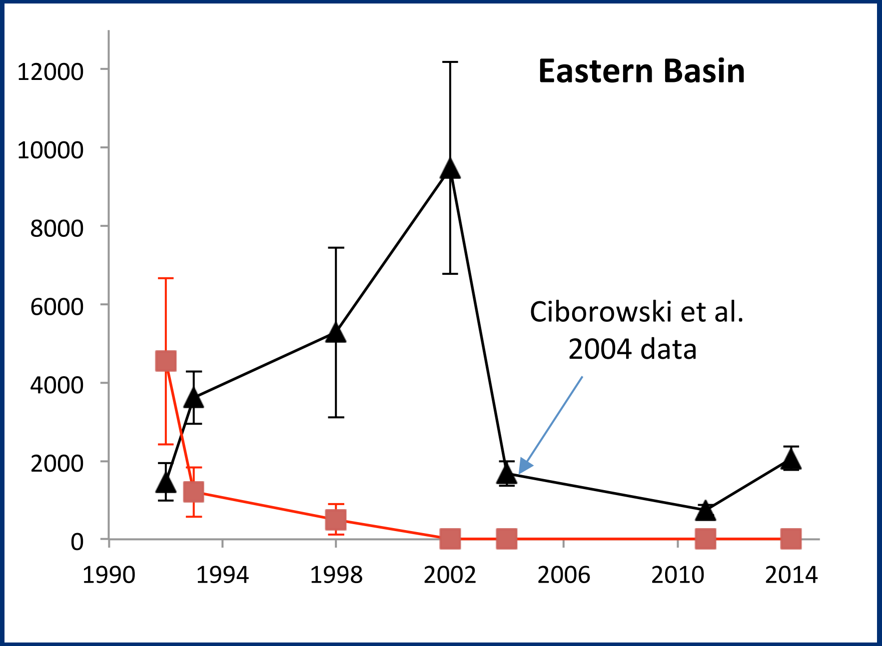


742 ± 126 m². Underestimation?



2,013 ± 288 m². Realistic?



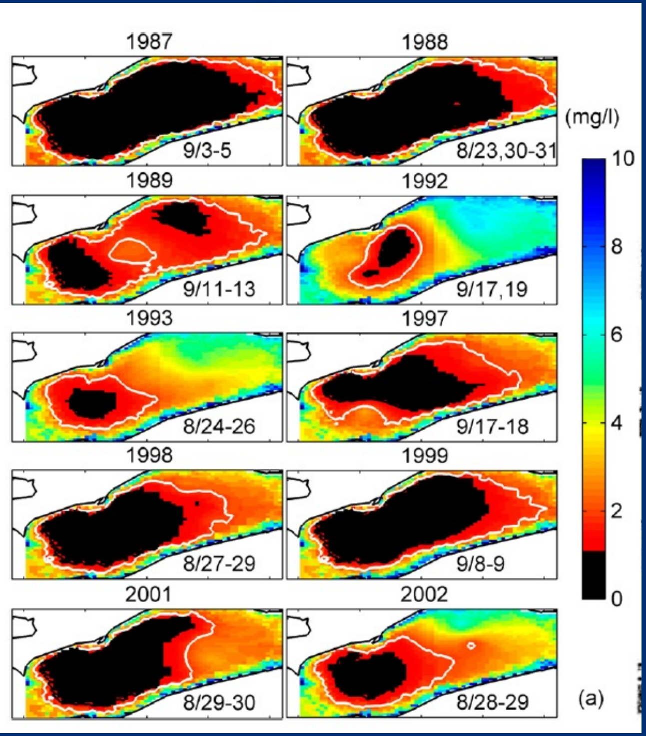


Central basin

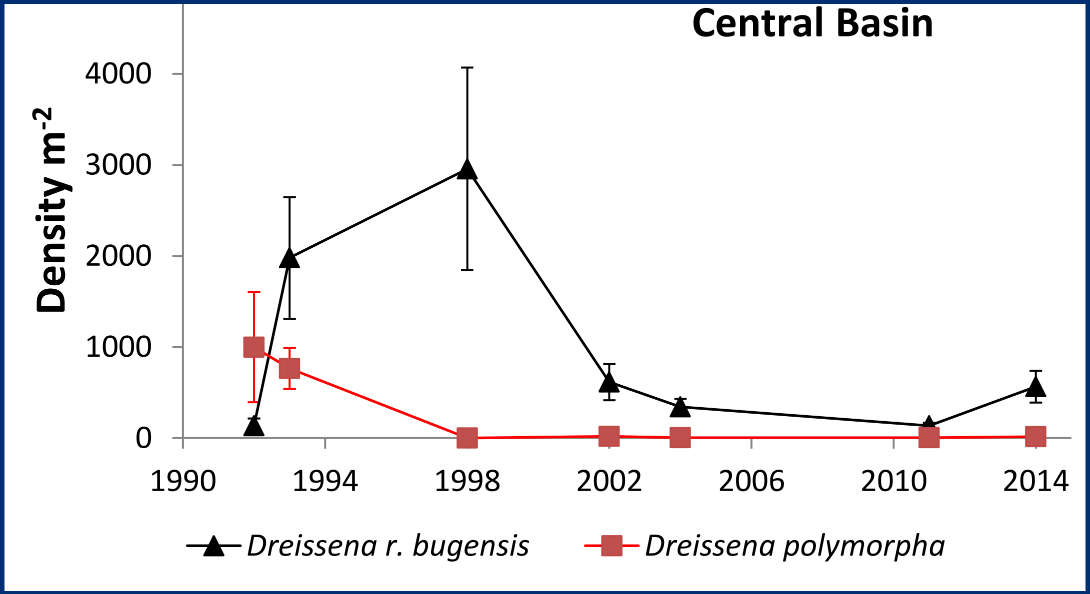
Could dreissenids define the hypoxic zone?

Hypoxia study: Lake Erie Central Basin

Much of the central basin was hypoxic during the height of eutrophication (1950s-70s), and hypoxia diminished in the 1980s and early 1990s when effects of P abatement programs took hold. However, since the late 1990s hypoxia has returned (reviewed in Vanderploeg et al. 2009)

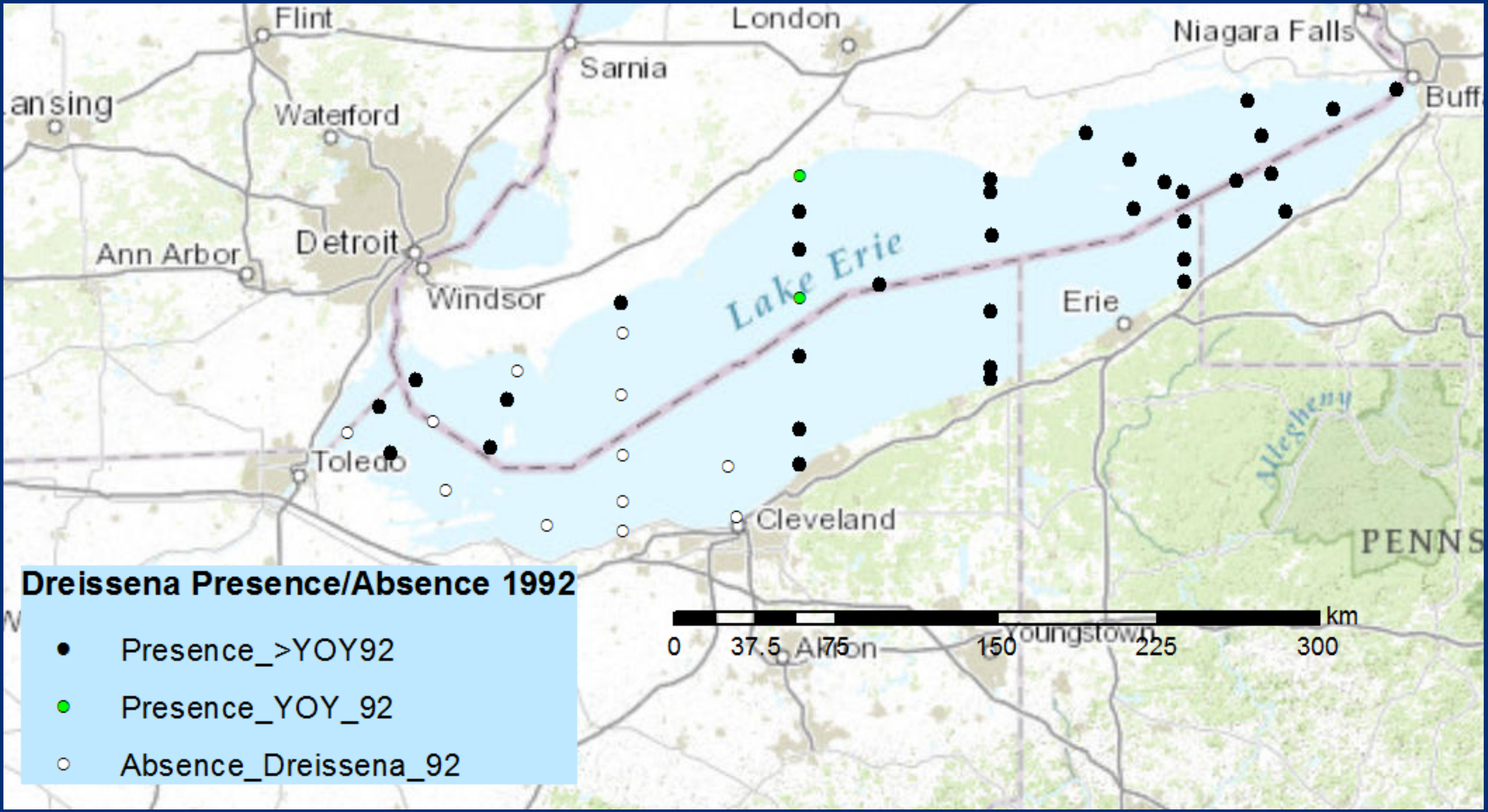


Zhou et al., 2013



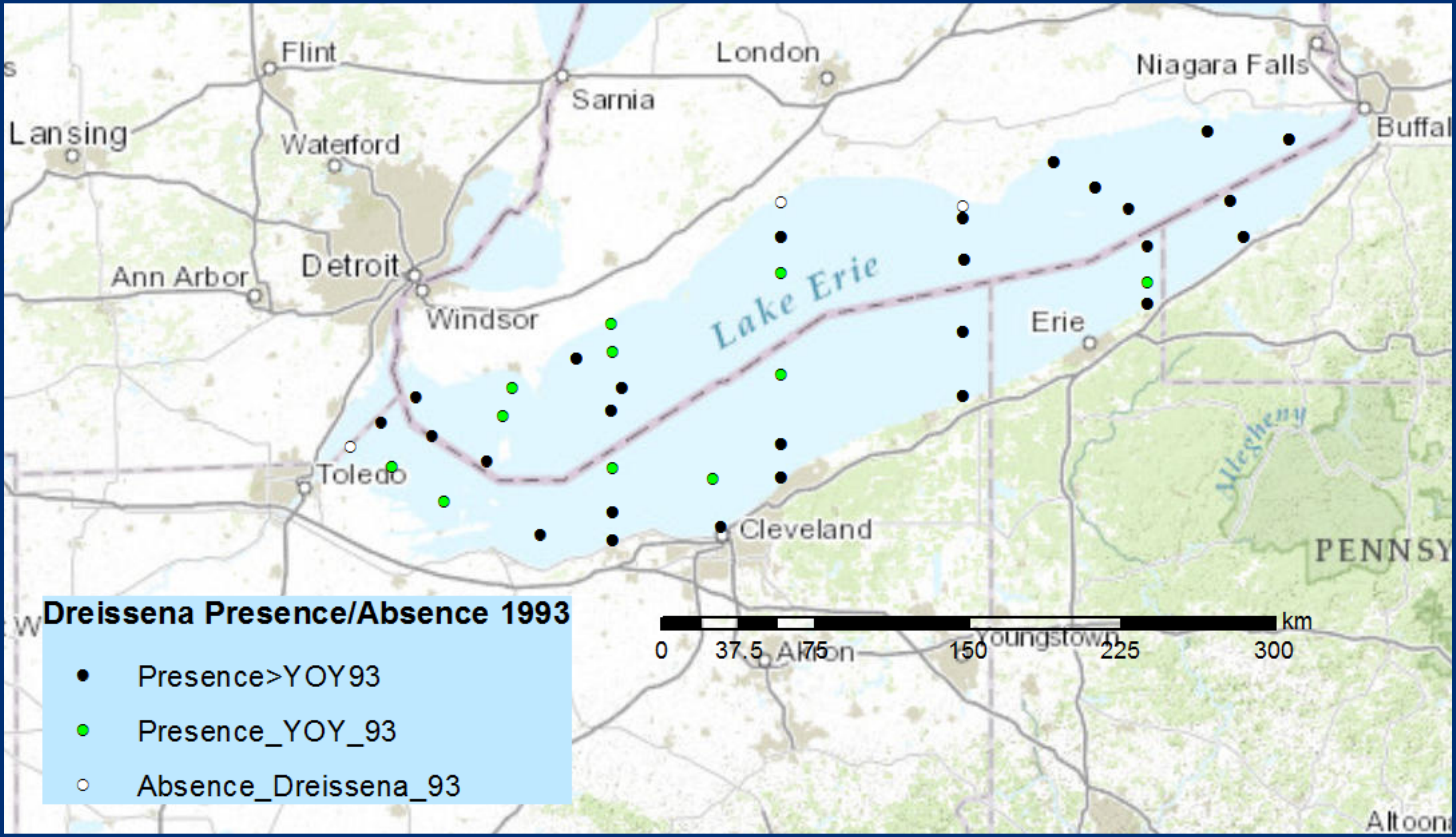
- The return of hypoxia coincided with the collapse of quagga mussels
- After 1998 their density declined almost 10 fold and never recovered since
- It was suggested that mussel distribution could map the hypoxic zone

Dreissena spp. distribution in Lake Erie in 1992



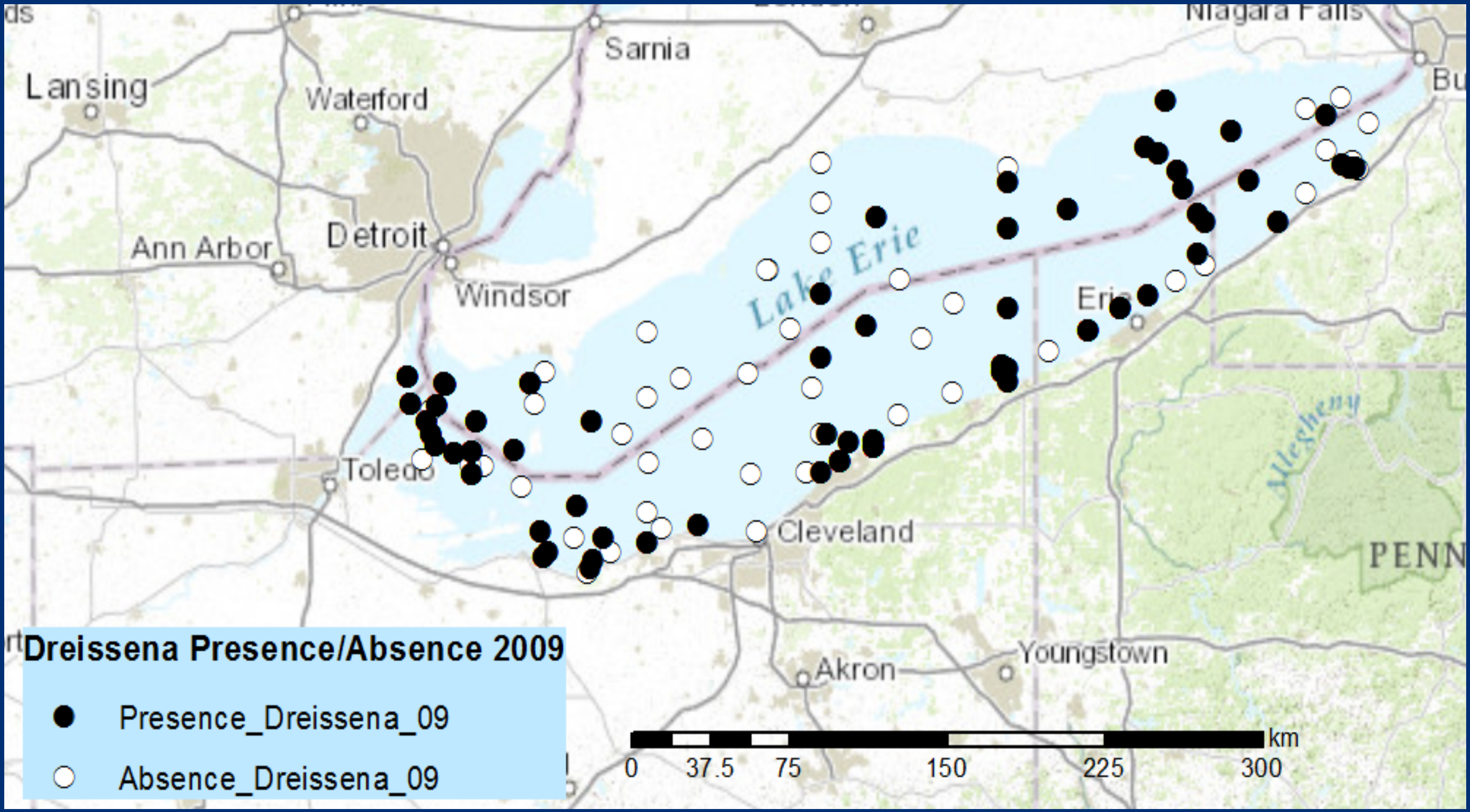
Dreissena present in central basin → no hypoxia

Dreissena spp. distribution in Lake Erie in 1993



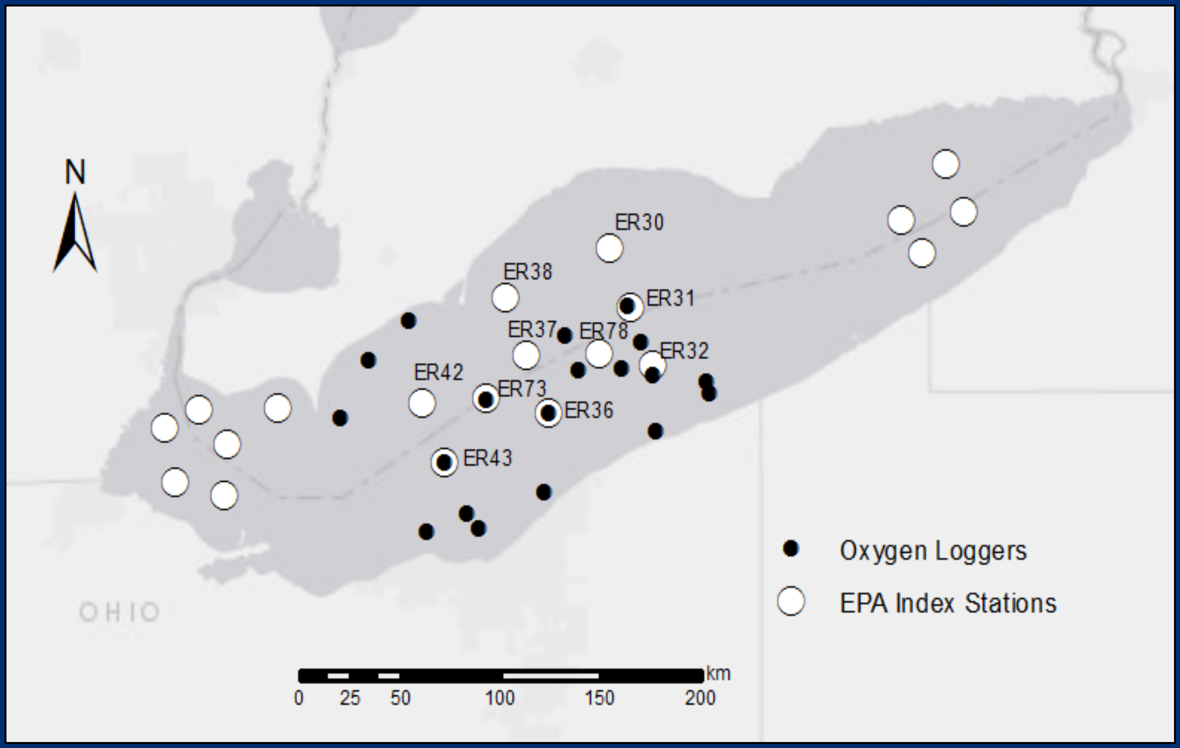
Dreissena present in central basin → no hypoxia

Dreissena spp. distribution in Lake Erie in 2009



Dreissena absent in central basin → larger hypoxia

2014 Lake Erie oxygen study



- We measured bottom dissolved oxygen using 19 data loggers from June through October at 10 minute intervals
- We used these data to validate a 3-dimensional hydrodynamic-ecological model simulating dissolved oxygen distribution, and compared predicted values with the distribution of *Dreissena*

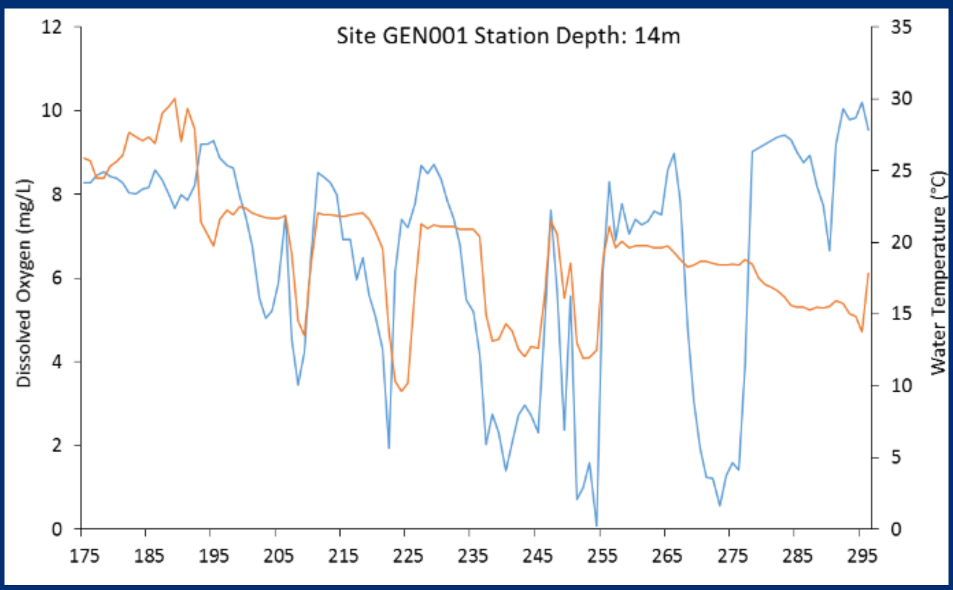
Dreissena mussels distribution in Lake Erie in 2014

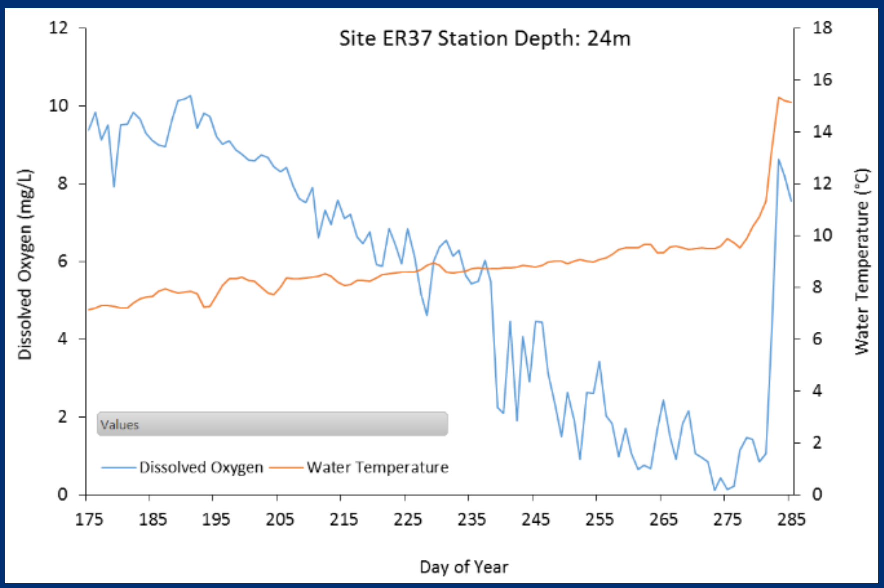
Basin, depth, m	Frequency	Density, m2	Biomass, g m2
Western basin, 0-10	100	3243 ± 2009	279.8 ± 150.4
Western basin, >10	88	2144 ± 1108	229.3 ± 107.2
Western basin, Average		**2844±1324**	**261.4±101.7**
Central basin, 0-10	75	1249 ± 1012	235.2 ± 231.9
Central basin, 10-20	81	1110 ± 484	124.8 ± 56.7
Central basin, > 20	23	**2 ± 1**	**0.3 ± 0.3**
Central basin, Average		556±223	71.8±32.0
Eastern basin, 0-10	80	2645 ± 908	1897.4 ± 616.6
Eastern basin, 10-20	100	4021 ± 1338	2191.8 ± 555.8
Eastern basin, 20-40	92	**716±281**	**649.0 ± 236.6**
Eastern basin, >40	100	1793±214	2021.8 ± 183.3
Average		**2287±469**	**1625.3±239.8**

- In central basin at depth > 20 m *Dreissena* density and biomass were 2 – 3 orders of magnitude lower than in the same depth zone of the eastern basin

Lake Erie central basin hypoxia

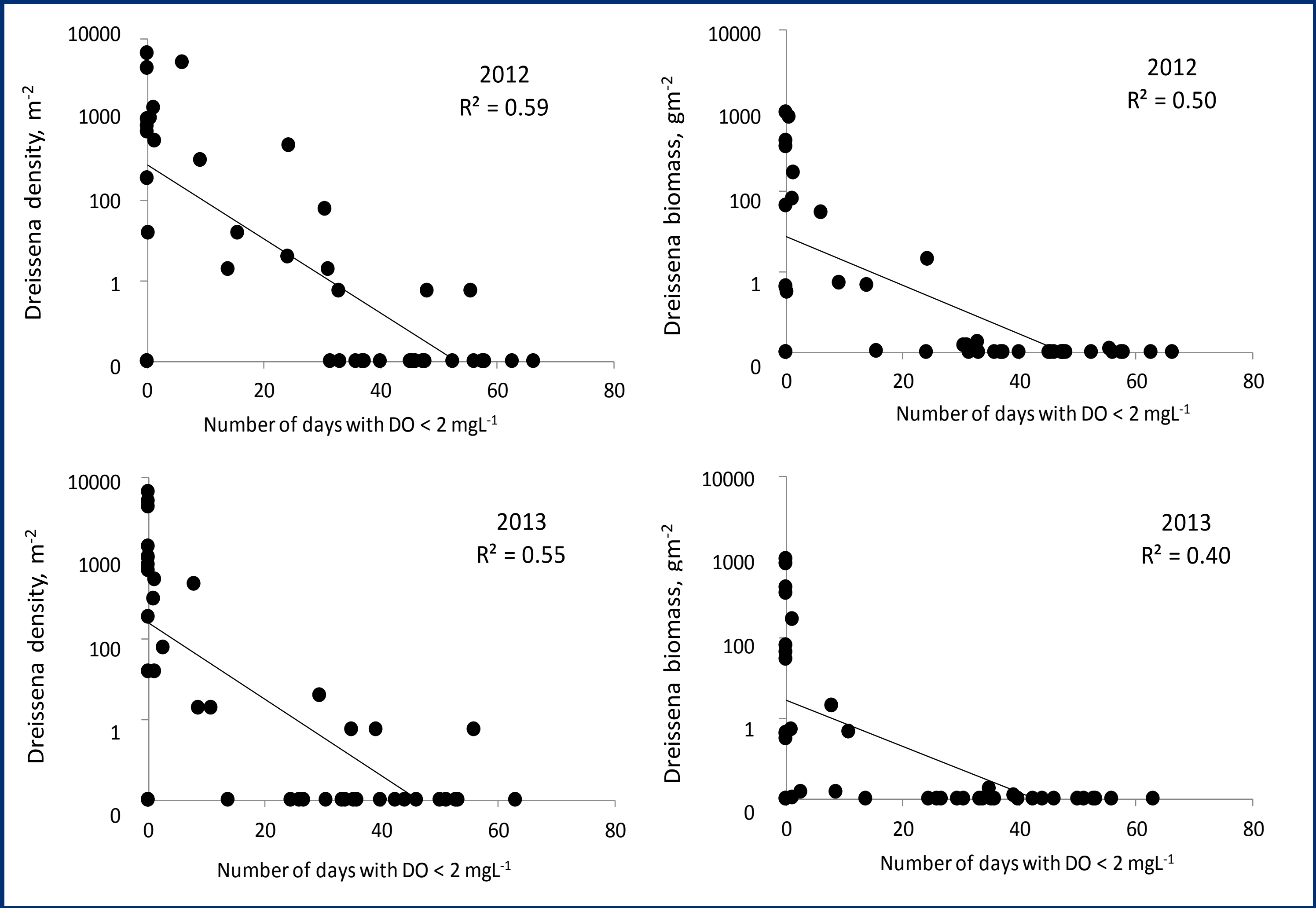
- Near bottom oxygen concentrations were high at the beginning of the season, but later dropped below 2 and even 1 mg L^{-1} forming hypoxic and anoxic zones respectively
- On October 4, a strong storm caused a complete mixing of the central basin, returning near bottom waters to normoxic conditions





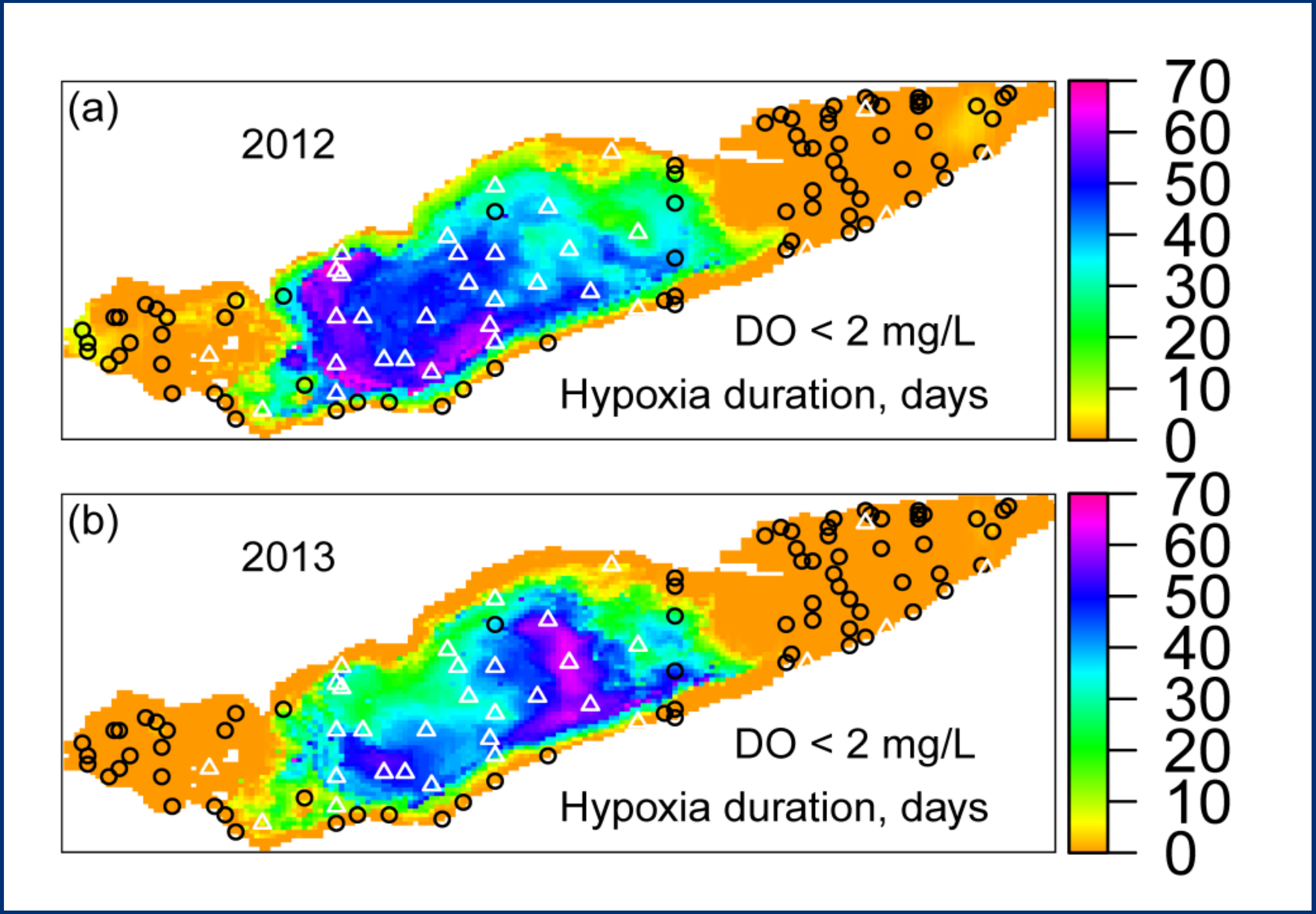
Dissolved oxygen (blue line, mg L^{-1}) and temperature (red line, ^{o}C) dynamics at two representative sites in Lake Erie. At shallow sites, oxygen and temperature were dynamic throughout the study. At deeper sites, oxygen decreased consistently while temperature remained relatively stable

Relationship between *Dreissena* density and the duration of near-bottom hypoxia in central basin



Highly significant correlations ($P << 0.001$) between *Dreissena* spp. density and biomass (2014) and the length of model-predicted near bottom hypoxic conditions (<2 mg L^{-1}) for 2012 and 2013

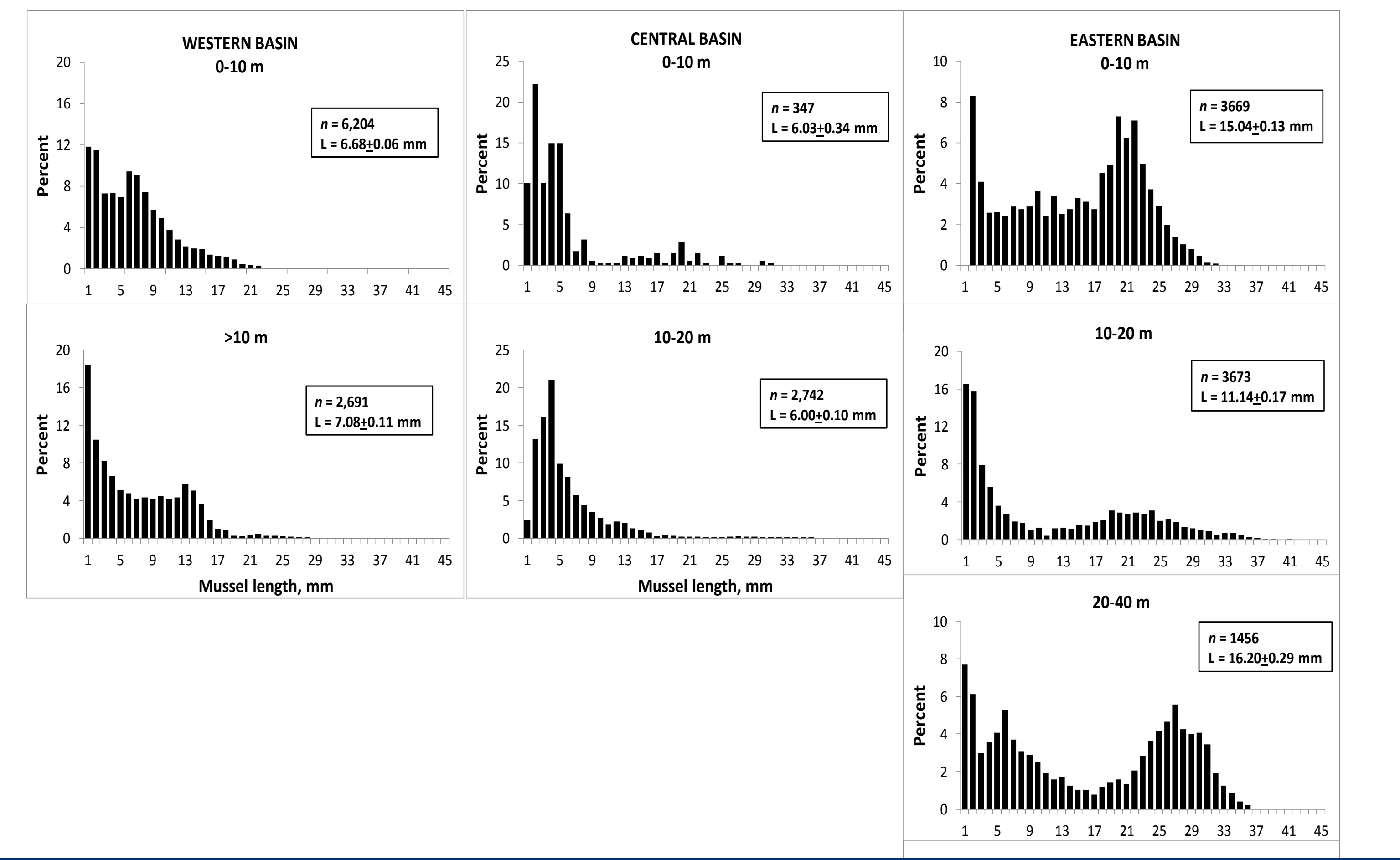
Spatial distribution of hypoxia vs. *Dreissena*



Spatial distribution of hypoxia with locations of stations sampled in 2014

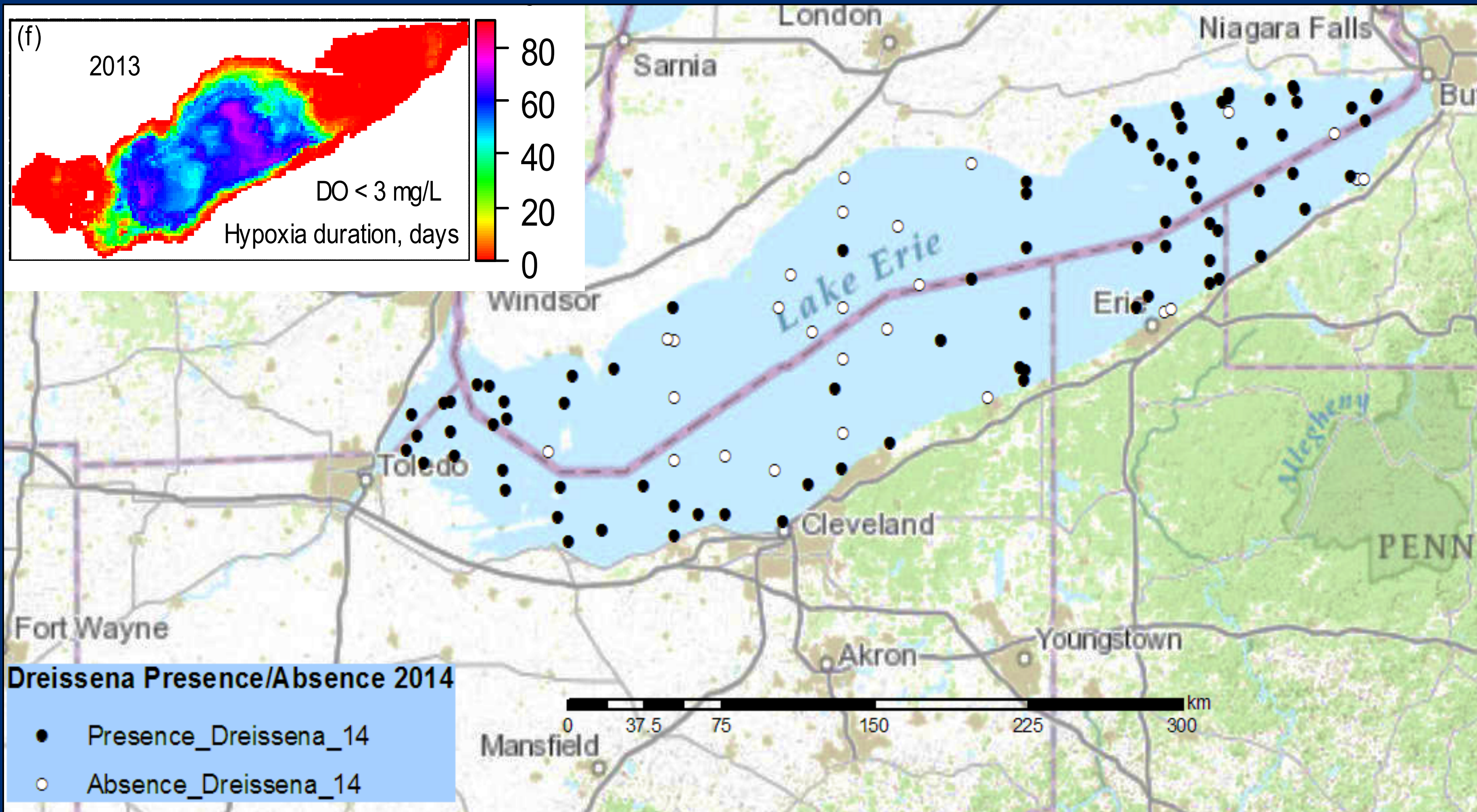
- Circles – *Dreissena* present
- Triangles – *Dreissena* absent.

Length-frequency distribution of *Dreissena* in Lake Erie



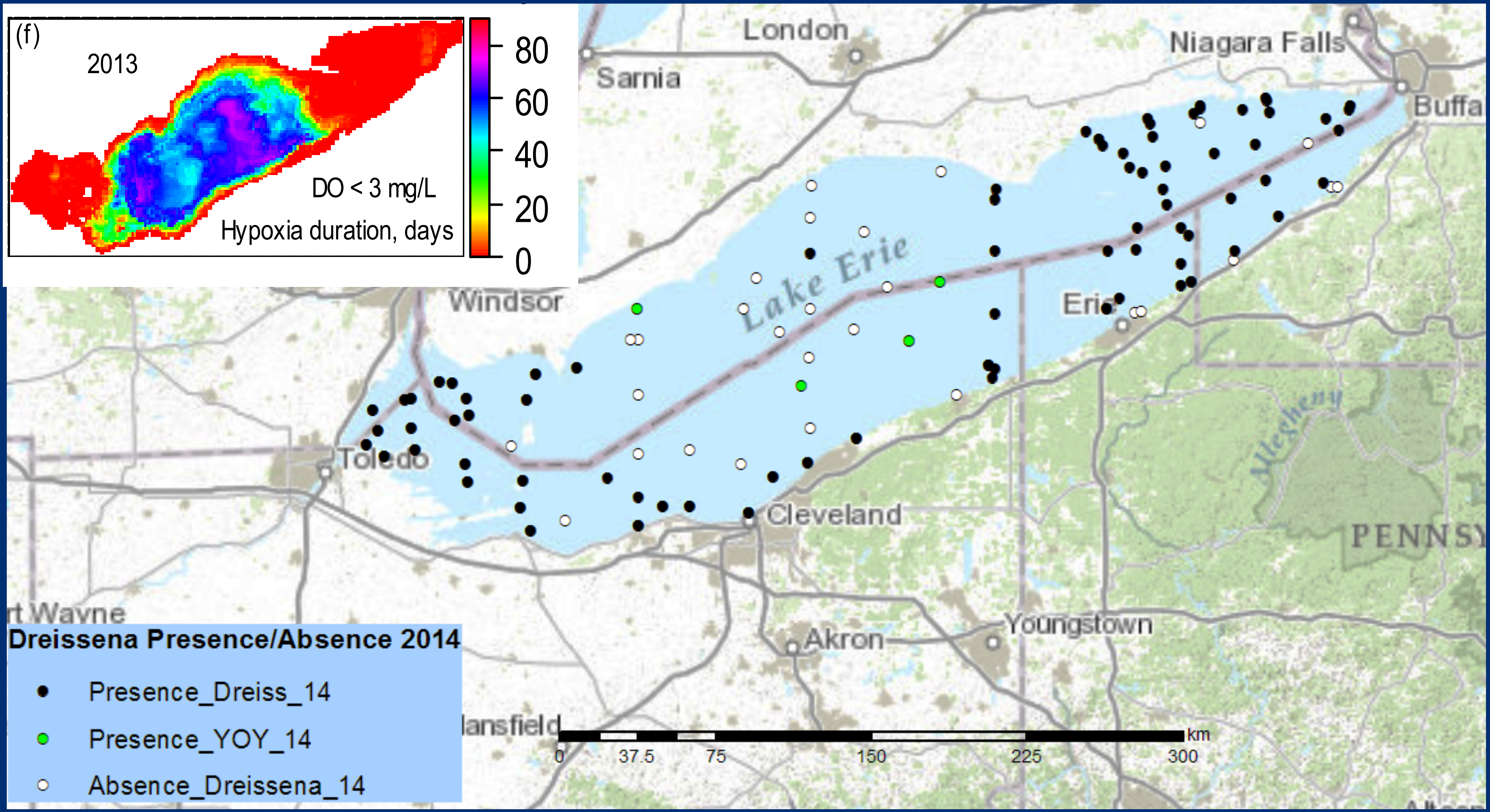
- Only young of the year mussels found in the central basin were bottom hypoxia routinely develops, indicating limited recruitment and survival
- Presence of old mussels across throughout the eastern basin suggests a lack of hypoxia and a more stable environment

Dreissena spp. distribution in Lake Erie in 2014



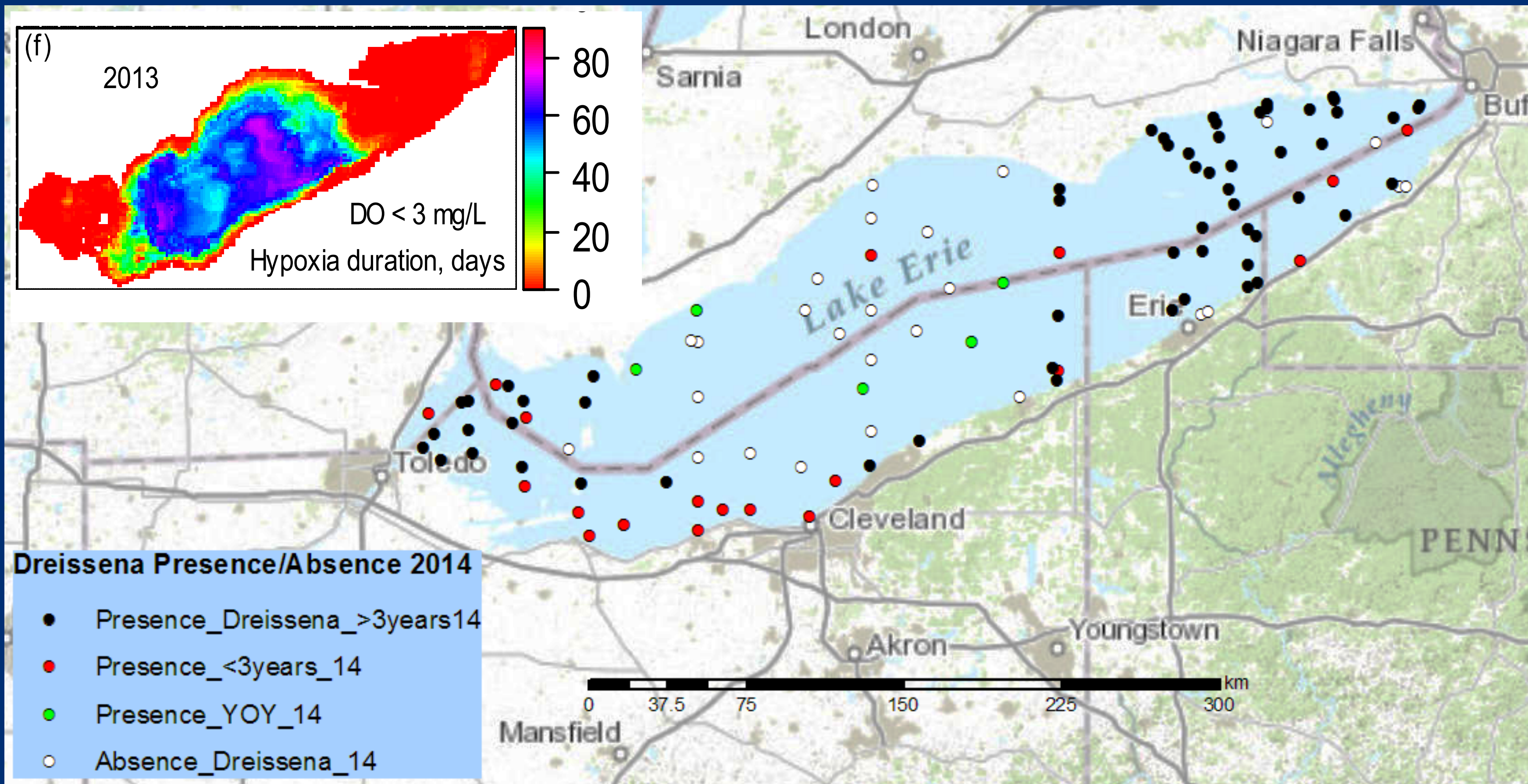
- *Dreissena* spp. absence may define the hypoxic zone
- How about black circles in the middle of the basin?

Dreissena spp. distribution in Lake Erie in 2014



Presence of only YOY mussels suggests a die-off event at least once a year, most likely due to hypoxia

Dreissena spp. distribution in Lake Erie in 2014



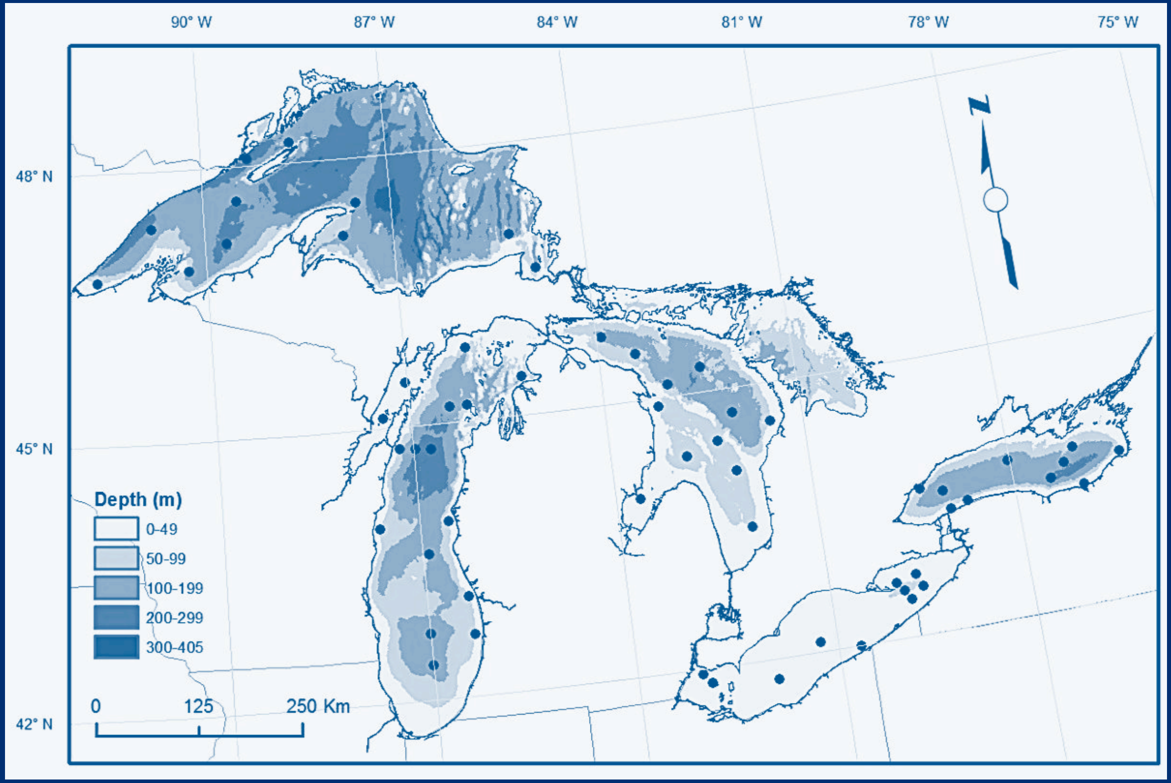
Presence of only < 3 years old mussels suggests a die-off event once every 3 years, most likely due to hypoxia

Management implications

- Persistent hypoxia effectively excludes *Dreissena* populations in the profundal zone of Lake Erie's central basin
- Ongoing efforts to strongly reduce total phosphorus load to decrease nuisance algal growth and minimize the hypoxic zone **may open up the profundal zone of the central basin for *Dreissena* expansion**
- Mandated reductions in nutrient loading of the ecosystems should be accompanied by monitoring efforts focused on the distribution and impacts of *Dreissena* in the profundal zone

U. S. EPA GLNPO Benthic Monitoring Program

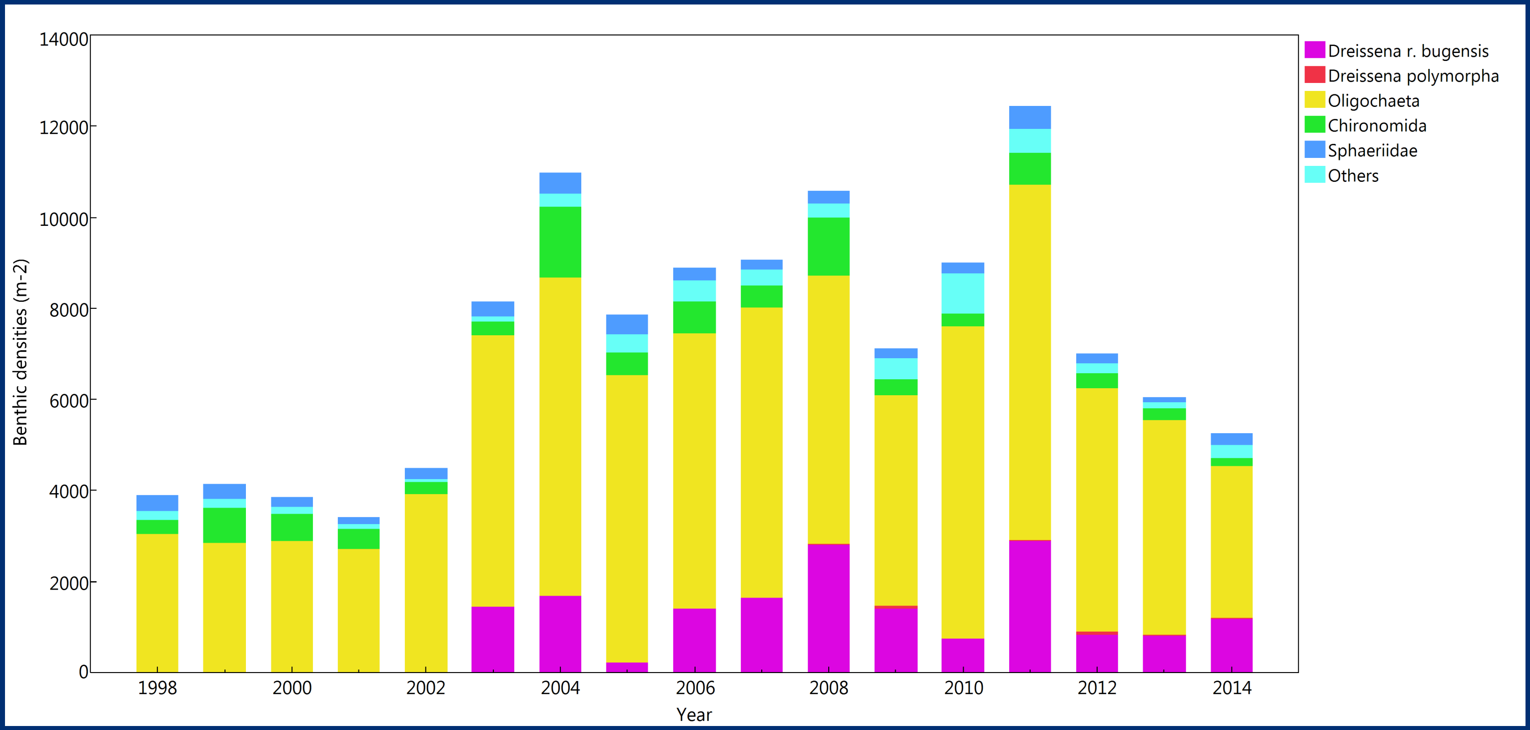
- Benthic biomonitoring program started in 1997
- 58 stations on all five Great Lakes sampled annually (triple PONAR grabs at each station)



Main trends in benthic taxa in Lake Erie

(GLNPO data 1998-2014)

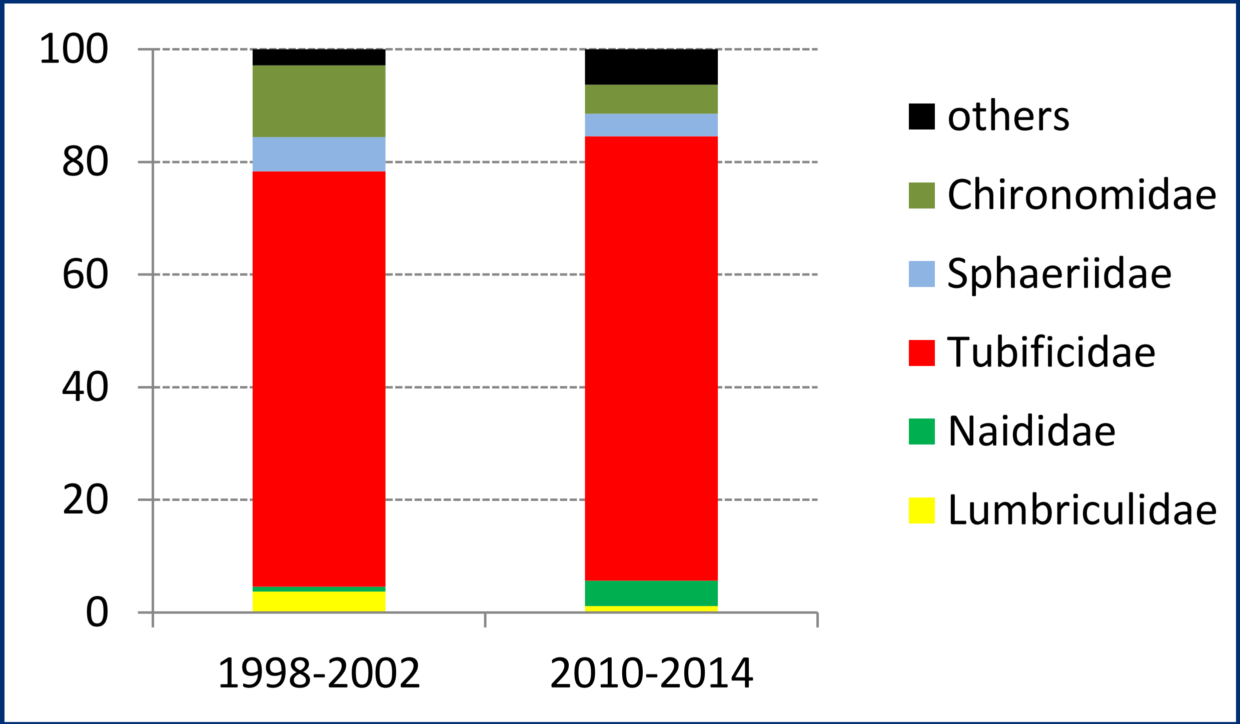
- Total benthic density increased lake-wide
- The trend was positive even without consideration of *Dreissena*



***Dreissena* was not recorded**

Shift in dominant species
(excluding Dreissena)

- Proportion of intolerant to organic pollution oligochaetes (Lumbriculidae) decreased 4 times, while pollution-tolerant (Tubificidae and Naididae) increasaed lake-wide
- Densities of bivalves Sphaeriidae decreased 2-fold

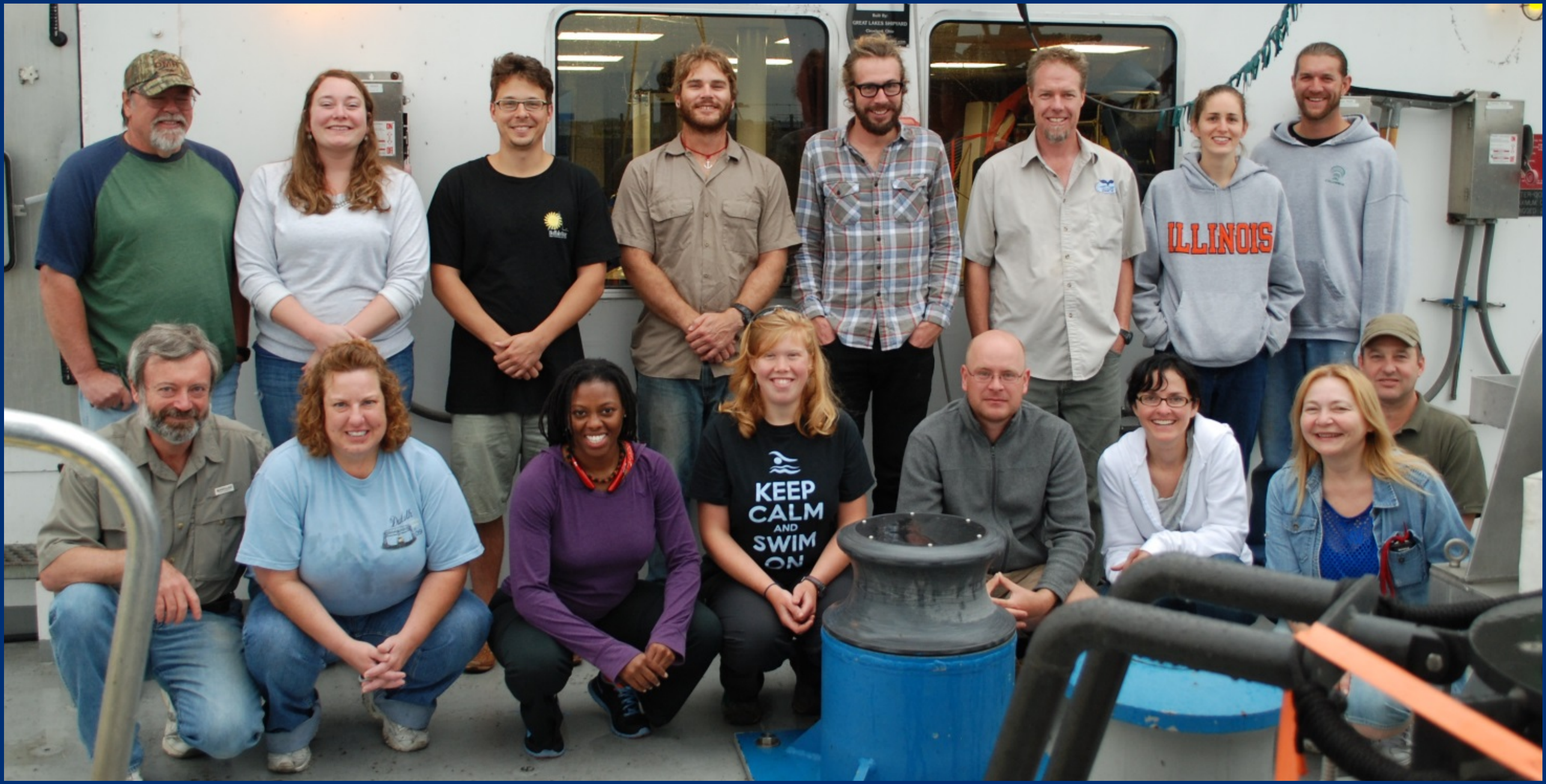


From: Burlakova, Barbiero, Karatayev, Daniel (in preparation). ***Benthic community of Laurentian Great Lakes: spatial gradients and temporal changes*** To be submitted to the *Journal of Great Lakes Research*, Special Issue (#5, 2017) *"U.S. EPA Great Lakes National Program Office Long-Term Monitoring of the Laurentian Great Lakes: approaches, achievements and lessons learned"*

Sediment samples

- In 2015 sediment samples (for grain size, TP, TN, and TOC) were collected at all long-term monitoring sites and at all sites during the CSMI Lake Michigan sampling *(last time sediments were studied in 2002)*
- First results will be presented at IAGLR 2017 (Daniel, Burlakova, Karatayev, Meyer, Hinchey, "*The effect of Dreissena on sediment organic matter and Oligochaeta in the Great Lakes*").
- Please see Kathryn Meyer (ORISE Fellow, GLNPO) for more information

Acknowledgments



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- We would like to thank all EPA and Buffalo State employees and students for their help in collecting and processing samples
- Our special thanks to the *Lake Guardian* Captain and crew for technical assistance and for providing an excellent working environment during the cruise.