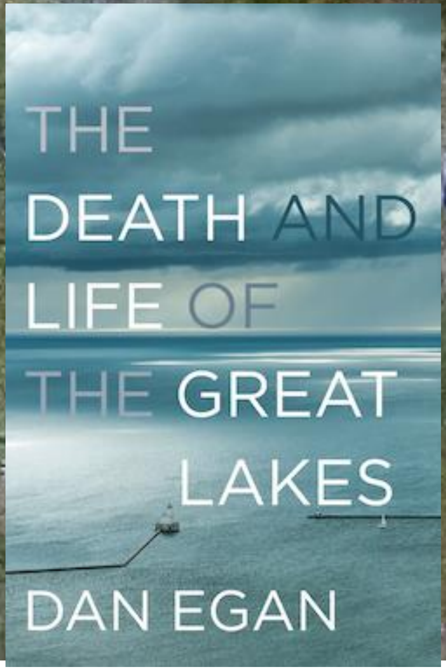
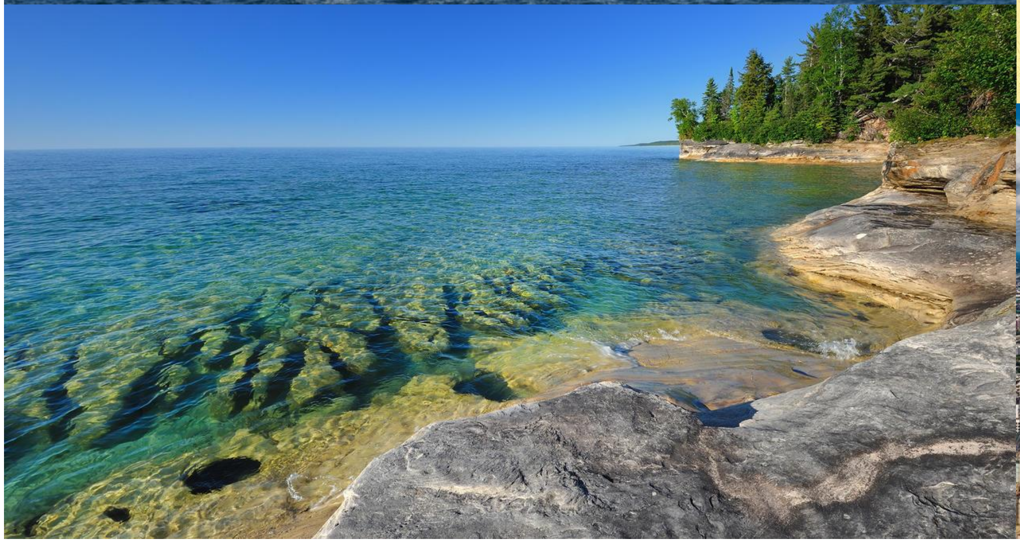
Александр Юрьевич Каратаев

Экологические проблемы Великих Американских Озер

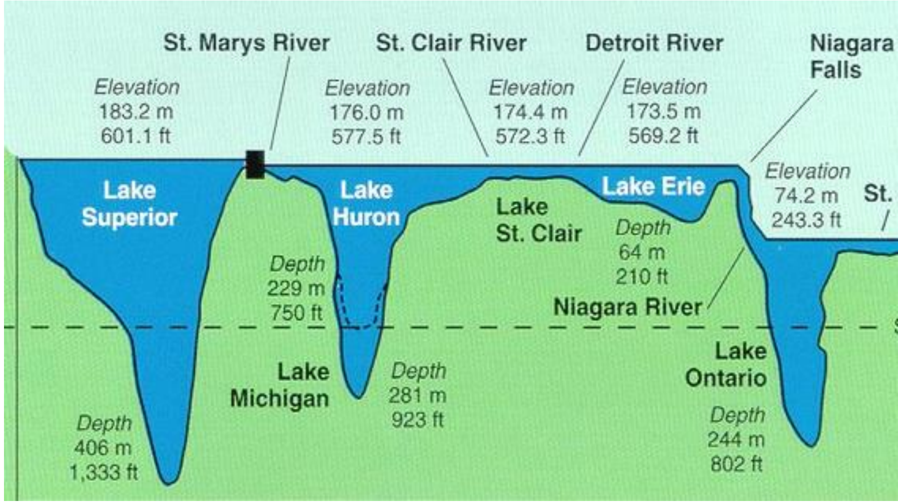


Laurentian Great Lakes

- 84% of North America's surface fresh water
- ~21% of the world's supply of surface fresh water
- Largest inland water transportation system in the world
- 35 million people live in their watershed
- 7% of US and 25% of Canada agriculture



Physical Features



- Glacial Lakes (~10,000 years old)
  - Upper lakes: Superior, Michigan, Huron
  - Lower lakes: Erie, Ontario
- Drain through the Saint Lawrence River to the Atlantic Ocean
- Superior is the deepest, largest and coldest lake
- Erie the shallowest and warmest with the lowest retention time

Parameter	Superior	Michigan	Huron	Erie	Ontario	Total
Surface, km2	82,100	57,800	59,600	25,700	18,960	**244,160**
Volume	12,100	4,920	3,540	484	1,640	**22,684**
Maximum Depth, m	406	282	229	64	244	
Retention time, years	191	99	22	2.6	6	

History of the Problems: Logging

- There is a belief that native Americans did have substantial impacts on GL ecosystems
- Logging of GL forests was the first major transformation of the environment
- The Black Hawk War ended and in 1833 towns began to grow at the mouths of the Rivers (Milwaukee, Chicago, Detroit, Toledo, Buffalo, etc.)

Logging

- Nearly every stream and river was choked with logs which scraped river bottoms and banks, destroying vegetation and spreading sediments
- Some rivers were so choked with sawdust that lake fish were physically unable to enter to spawn
- Sawdust was highly inflammable, and destructive forest fires were frequent
- Chicago fire destroyed the city and killed 300 people

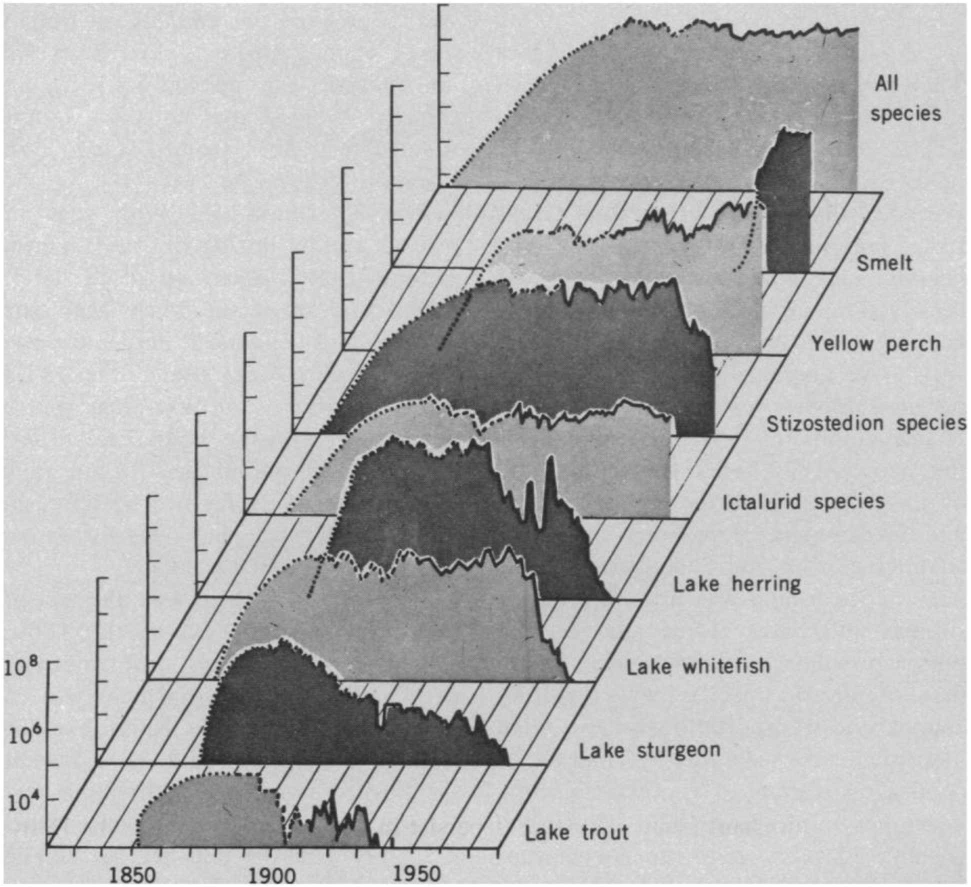
By the early 1900s, lumberjacks had logged Great Lakes forests

Agriculture

- After lumberjacks had logged forest, lands south of Erie became good farmland
- The Great Black Swamp was a wet forest of a million hectares. Soil erosion was limited, runoff waters were clean, river bottoms were free of silts. Nearly all the swamps were drained in the early 1900's
- Drainage for agriculture eliminated wetlands washing sediments into lakes
- Nutrients applied to fertilize crops drain into the GL, causing algal blooms

Commercial Fishery

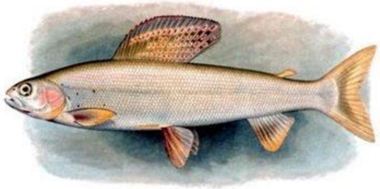
- Began after the War of 1812, and increased after 1820 about 20% per year
- By 1890's, some fishing enterprises collapsed because of overfishing of preferred species
- The introduction of nylon nets in 1950s resulted in the most intensive fishing in Lake Erie's history and drove some species to commercial or biological extinction



Extinct Fishes

- Blue pike commercial and sport fishers landed a billion pounds between 1885 and 1962, comprising > 50% of the commercial catch in Lake Erie. Population crashed in 1958, and extinct in 1970

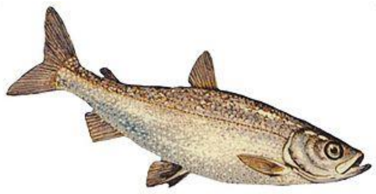
- Deepwater cisco extinct in the 1950s



- Blackfin cisco extinct in the 1960s

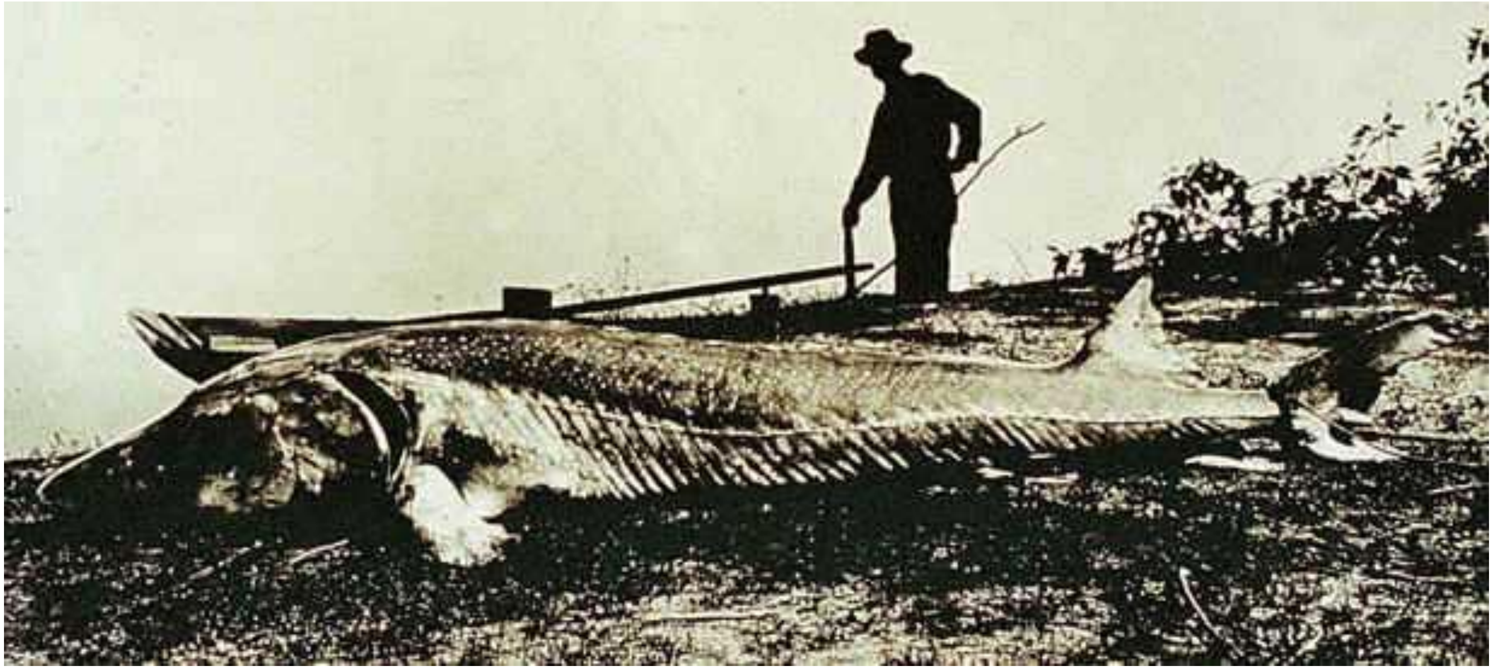
The Blackfin Cisco *Coregonus nigripinnis*

- Longjaw cisco extinct in the 1970s



Lake Sturgeon

- In the 1860s, sturgeon became a problem to the gill-net fishery for lake trout, lake herring, and whitefish. Fishermen made heavier nets to capture sturgeon and burn
- In 1860s an immigrant from Europe arrived with a knowledge of how to smoke it and manufacture caviar
- Between 1879 and 1900, the GL fishery averaged 1800 tons/year
- The fishery collapsed by 1900 and have never recovered. Currently, 19 of the 20 states list it as either threatened or endangered



Pollution

- Growth of population and economy and high demands for chemicals, rubber, steel, etc. for the second World War led to a major industrial expansion, resulting in large-scale chemical and heavy metal discharges to the lakes
- In the early and mid 20th century, Great Lakes and their tributaries were considered public sewers and waste disposal lagoons. “Industry was king,” and “dirty rivers were considered a sign of prosperity.”

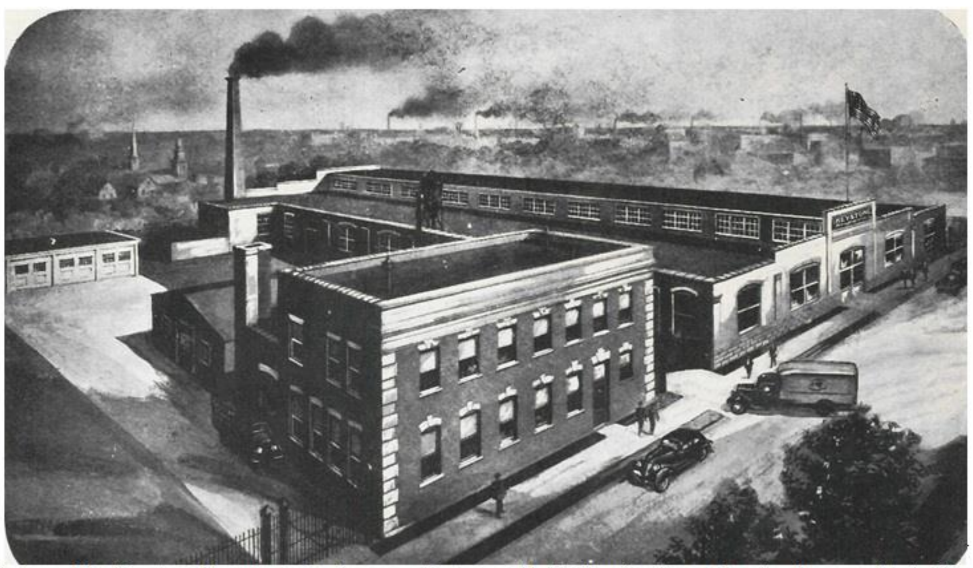
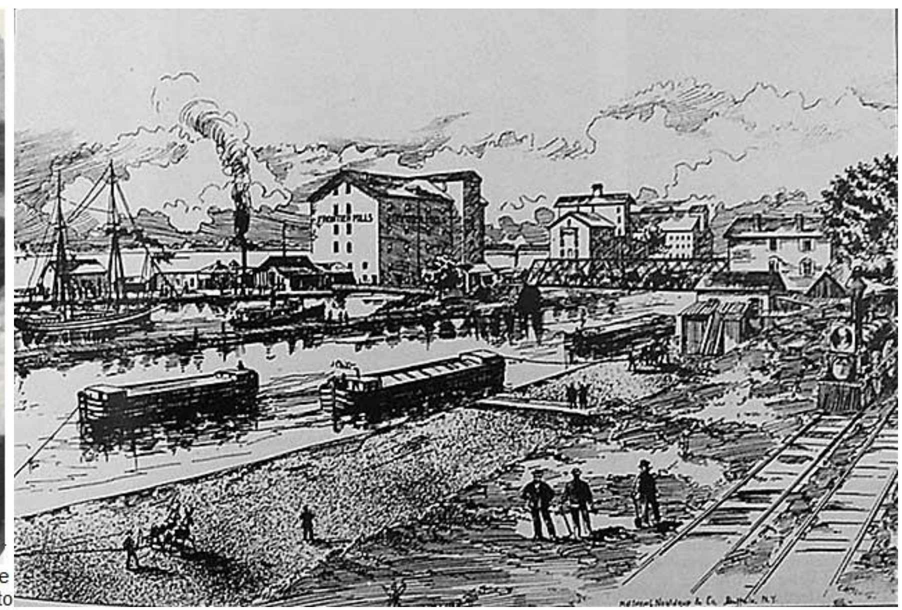
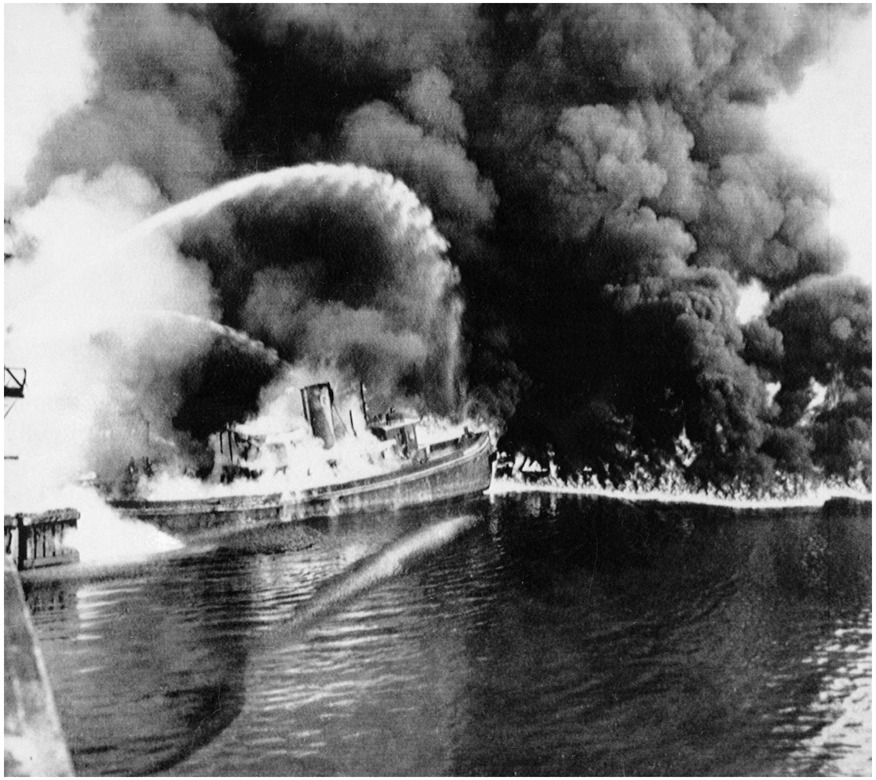


Image of the Keystone Manufacturing Company Factory at 41-63 Chandler Street showing the completed office block and factory space. Still present is the alleyway between the two buildings that would have allowed trucks to circulate through the factory.



“America's Dead Sea”

- The heaviest pollution occurred in the 1960s and 1970s when Lake Erie was called “America's Dead Sea”
- In 1969, the Cuyahoga River caught fire, similar fires occurred in Detroit and Buffalo areas
- The burning rivers and the "dead" lake were major drivers for the Federal government to step in and deal with water pollution
- In 1972, Congress passed the Clean Water Act that tightened regulations on industrial dumping



Signing of GLWQA 1972

The Great Lakes Water Quality Agreement (GLWQA) was first signed in 1972 to coordinate the actions of Canada and the US. The purpose of the GLWQA is:

"…to restore and maintain the chemical, physical, and biological integrity of the Waters of the Great Lakes."

Prime Minister Pierre Trudeau and President Richard Nixon signed the Canada-US Great Lakes Water Quality Agreement in recognition of the urgent need to improve environmental conditions in the Great Lakes

GLWQA 1972

- The chief objective of the 1972 Agreement was reductions of phosphorus loadings to control eutrophication
- Major investments in:
  - upgrading wastewater treatment plants,
  - improved agriculture,
  - reduction in phosphorus content of detergents,
- Improvements became obvious. Algal proliferation decline and more beaches were open and open longer for swimming and recreational use

Updated Great Lakes Water Quality Agreement 2012

- The original Great Lakes Water Quality Agreement resulted in significant progress in the restoration of Great Lakes
- However, because new environmental problems became evident, Canada and the United States amended the Agreement in 2012
- New agreement addresses:
  - nearshore environment
  - aquatic invasive species
  - habitat degradation
  - climate change
  - harmful algae
  - toxic chemicals
  - discharges from vessels

EPA Administrator Lisa Jackson and Canadian Environment Minister Peter Kent sign the Updated Great Lakes Water Quality Agreement

Great Lakes Restoration Initiative (GLRI)

- The Great Lakes Restoration Initiative was launched in 2010 to tackle the long-standing problems and emerging challenges that must be addressed to revitalize the Great Lakes ecosystem
- **GLRI received $2.56 billion in 2010 - 2017**
- All projects must support one of the GLRI focus areas:
  - Toxic Substances and Areas of Concern
  - **Invasive Species**
  - Nonpoint Source Pollution Impacts on Nearshore Health
  - **Habitat and Species**
  - Foundations for Future Restoration Actions (Accountability, Education, **Monitoring**, Evaluation, Communication and Partnerships)

GLRI became great source for funding of our research

Great Lakes Long-term Monitoring

- In collaboration with Cornell University, in 2012 we received $3.8 million grant from EPA for monitoring of all Great Lakes
- In 2017 we received $5.7 million from EPA for monitoring for 2017-2022
- Long-term monitoring of Great Lakes water quality and fish food resources produces data important for over 30 million people living on the Great Lakes watershed

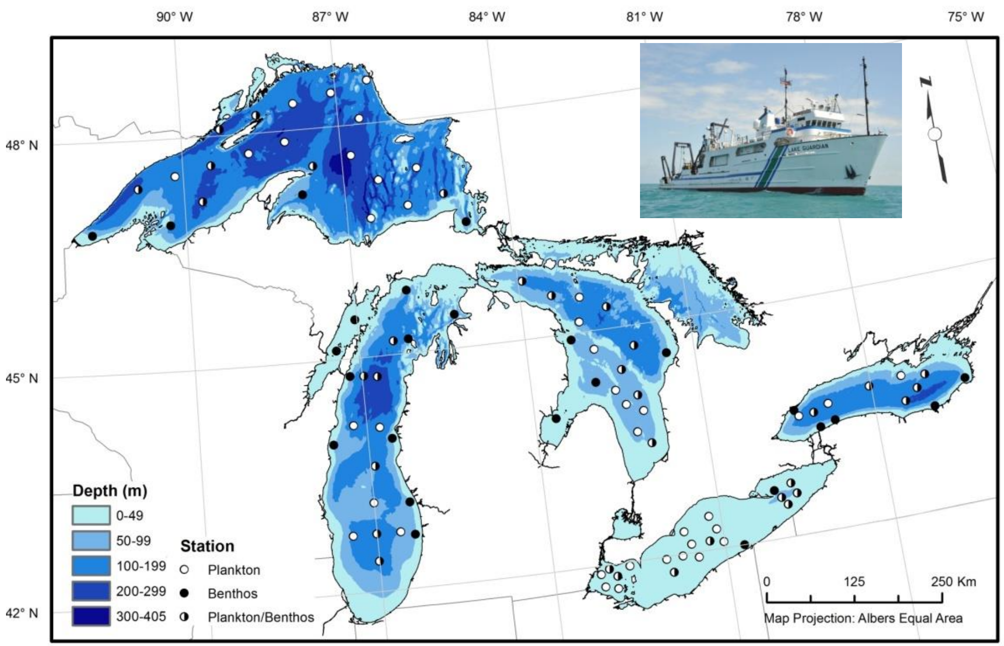
US EPA Monitoring of the Lower Food Web in the Laurentian Great Lakes Started in 1983

Administrated by Great Lakes National Program Office (GLNPO)

Lower Food Web Variables:

- Chemistry
- Secchi depth
- Chlorophyll
- Phytoplankton
- Zooplankton
- **Zoobenthos (since 1997)**

Great Lakes National Program Office (GLNPO)

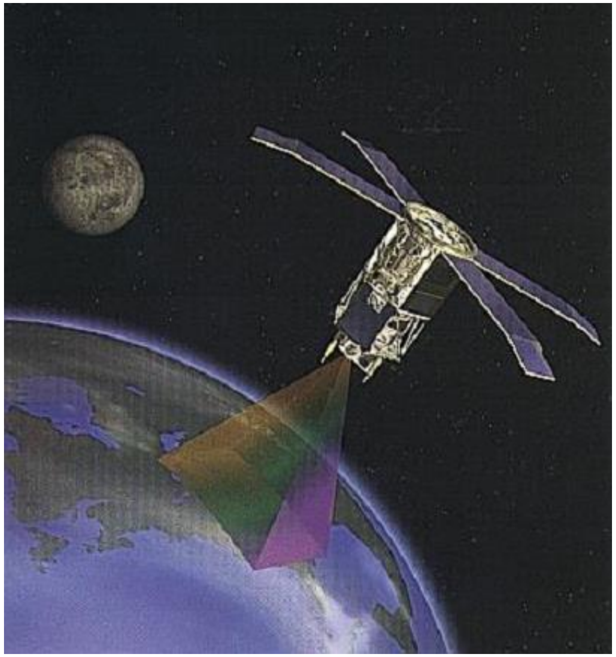


Map by Justin Telech

- Annual spring, summer surveys Since 1983
- Summer benthos surveys Since 1997

Remote Sensing Chlorophyll *a*

- SeaWiFS – 1998-2007
- MODIS – 2008-2018
- Data extracted from GLNPO sites
- Algorithm specific to Great Lakes (Lesht et al., 2013)



Lake Guardian Largest R/V on Great Lakes

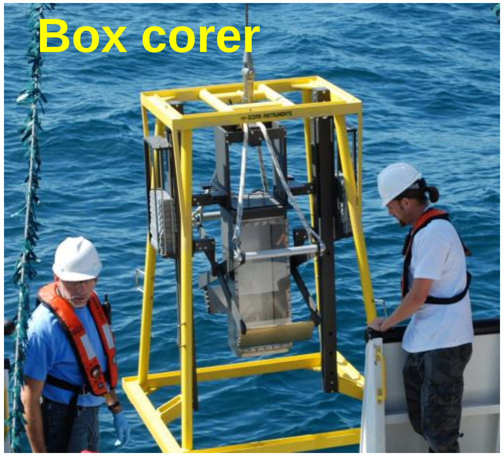
- Length - 180 feet
- Gross tonnage - 283 tons
- Cruising speed - 11 knots
- Crew members - 14
- Visiting scientists - 27

Lake Guardian Largest R/V on Great Lakes

Three dedicated laboratories:

- General purpose or "wet" laboratory
- Chemistry laboratory
- Biology laboratory

Benthic Sampling Equipment:



Everybody Welcome

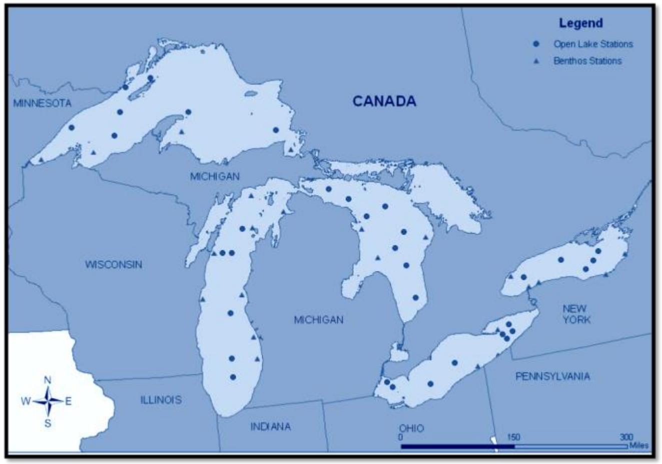
During monitoring surveys, EPA offers opportunities for scientists from federal and state governments and universities to conduct research aboard the R/V *Lake Guardian*. Research compatible with the standard sampling performed at each station is especially encouraged.

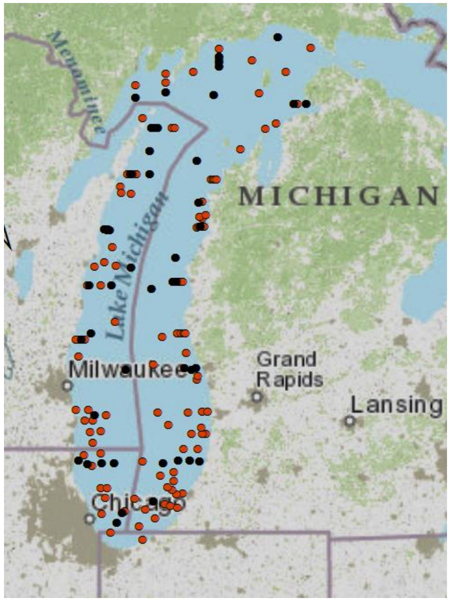
The vessel is dry (absolutely no alcohol!!!)

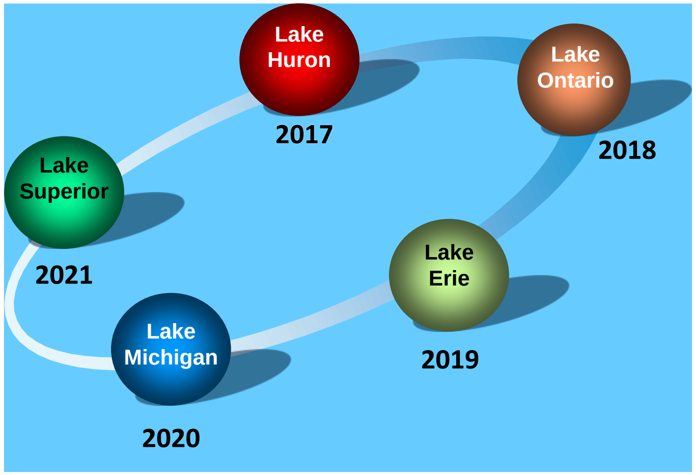
Benthic Monitoring in the Great Lakes

Two spatial and temporal components:

- Few LTM stations every year in all 5 lakes (low spatial, high temporal resolution)







- Intensive survey of one lake per year (high spatial, low temporal resolution)

The amount of samples to be analyzed, the scope of the study, and the significance of the Great Lakes make us responsible for the largest benthic monitoring program in the Great Lakes region and one of the largest in the world

Benthic Monitoring in the Great Lakes

On a regular benthic survey we collect samples from 60 - 140 stations, including:

- Triplicate Ponar samples (for all benthos)
- GoPro video images attached to Ponar
- Benthic tows with GoPro camera (for *Dreissena* distribution analysis)

Additional samples include:

- Rosette cast (chlorophyll, DO, conductivity, temperature, depth)
- Sediment granulometry
- Sediment chemistry

All actual sampling conducted by marine techs. Scientists responsible for samples processing, preservation, labeling, etc.

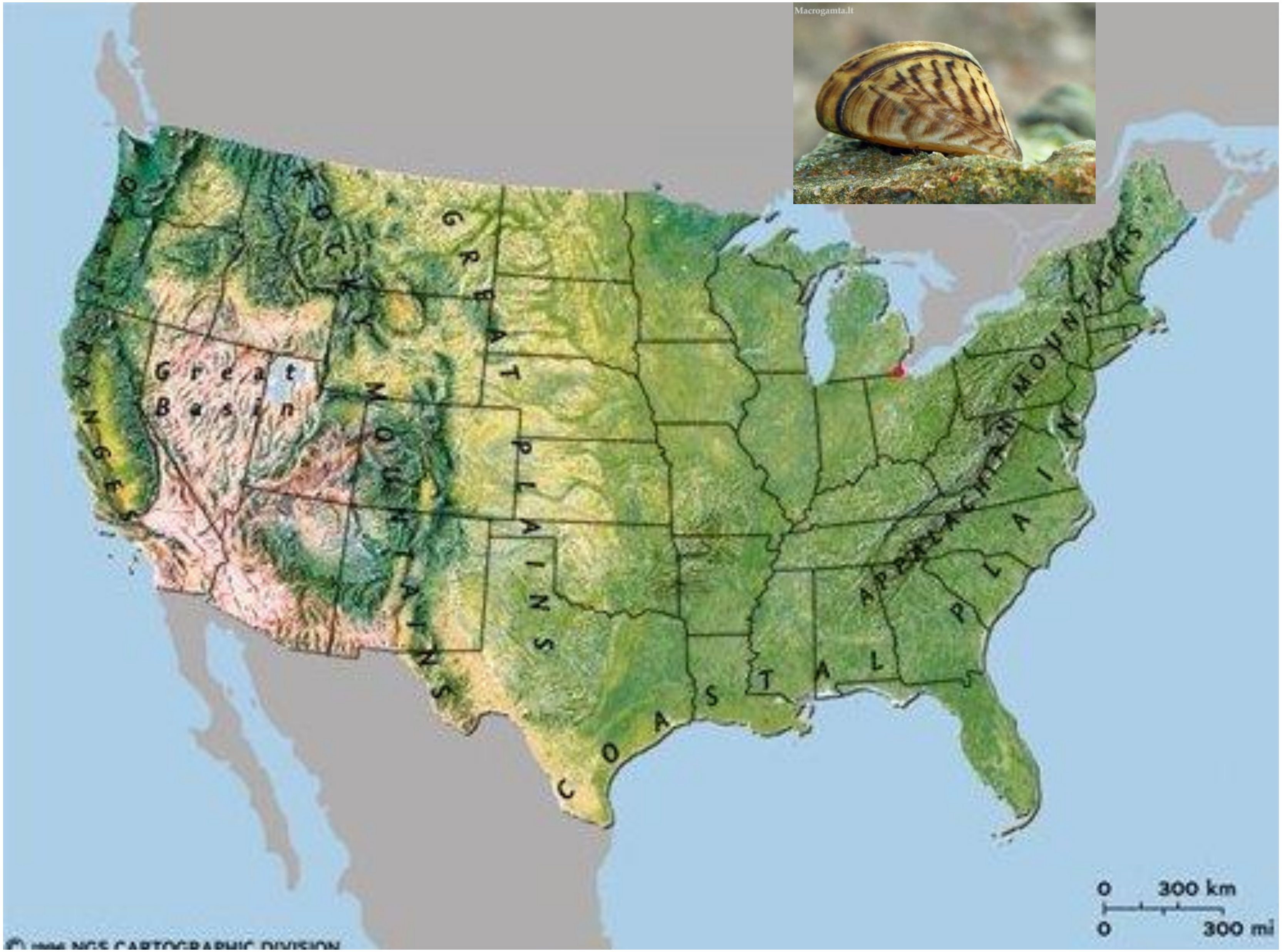
Monitoring of *Dreissena* Population

Since 1980s, *Dreissena* became one of the major drivers of Great Lake Ecosystems

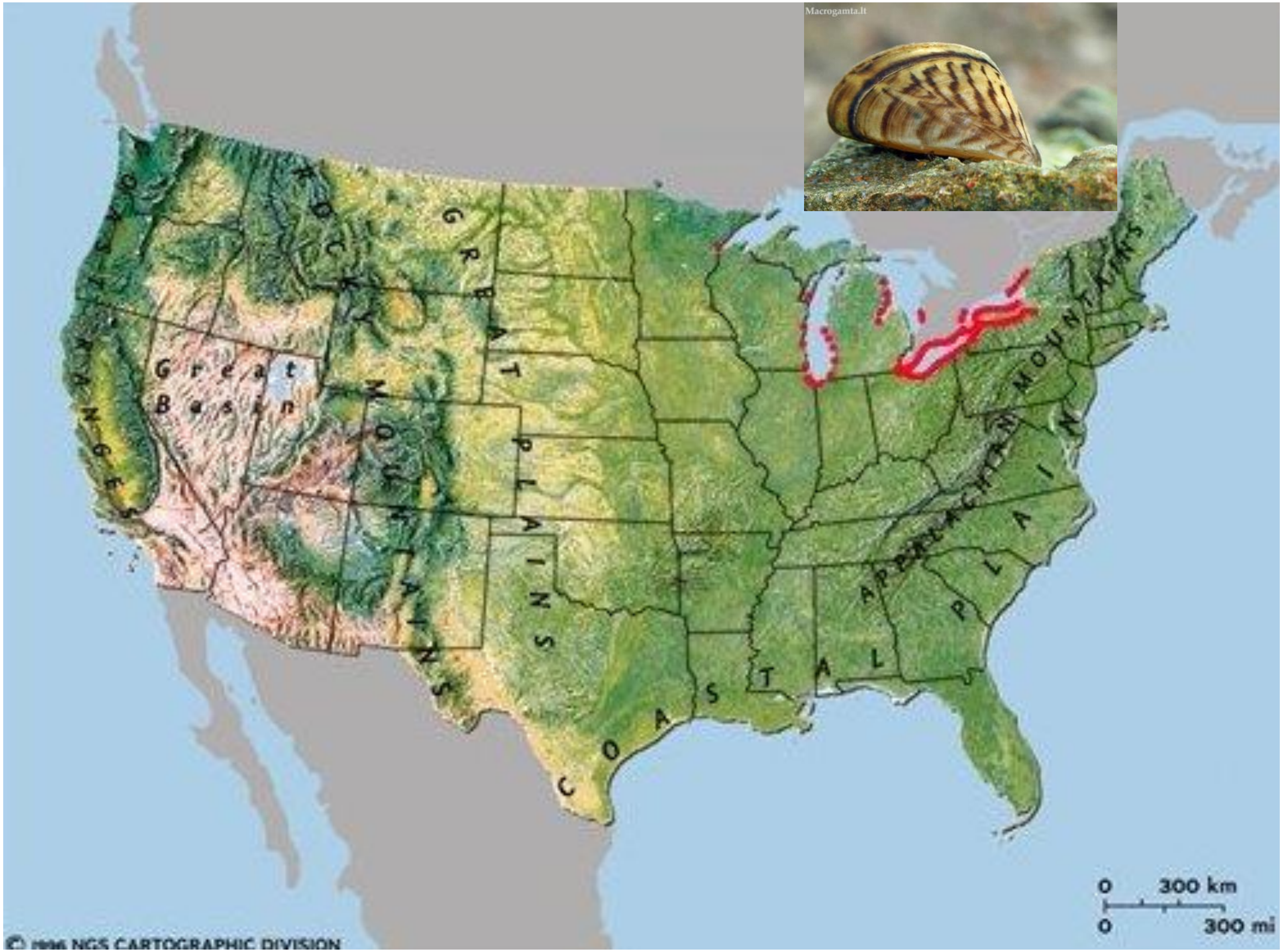
In order to predict *Dreissena* ecological impacts we need to know:

- where they are
- how many of them are there
- are their populations increasing or decreasing

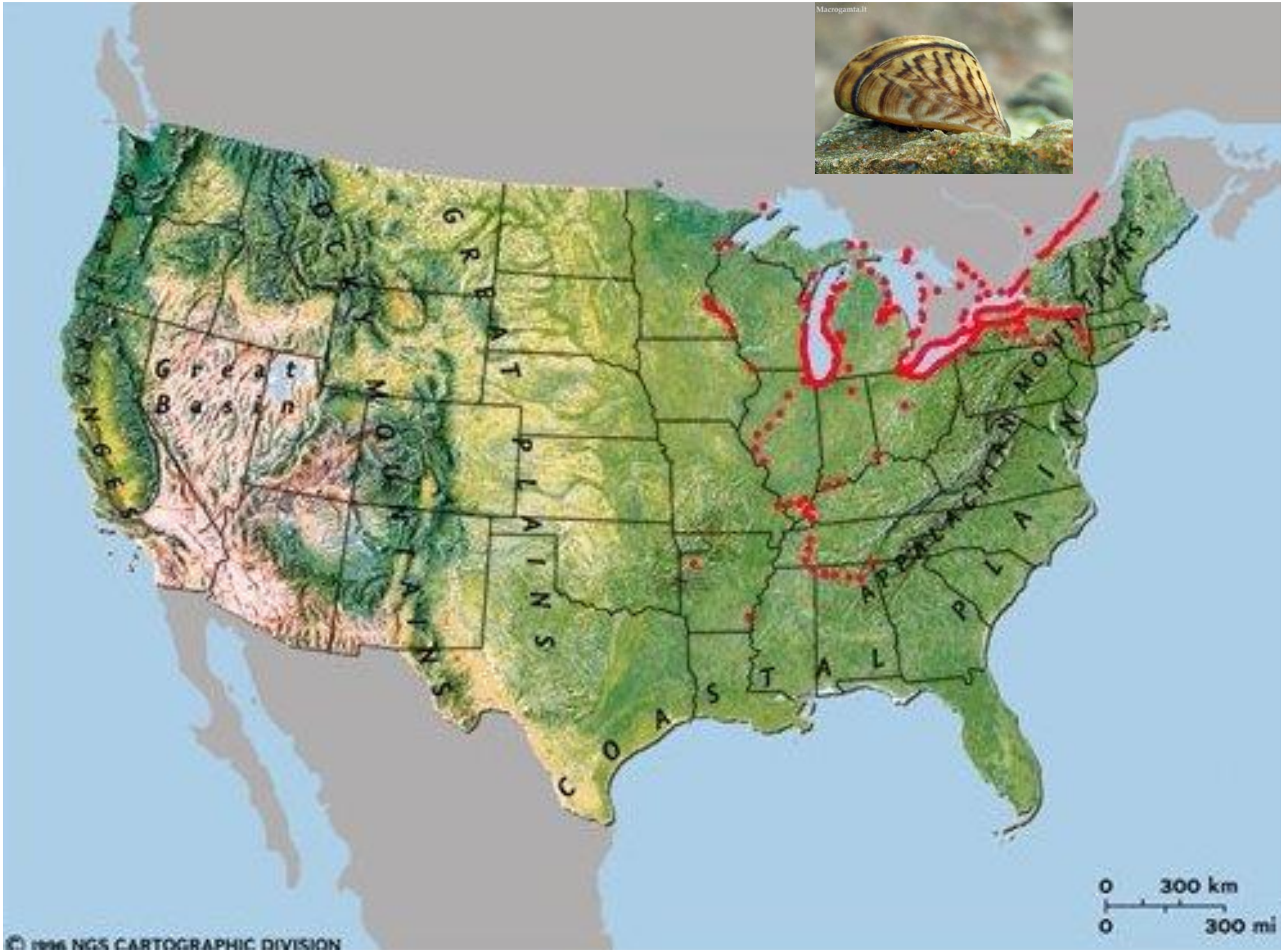
Zebra Mussel Spread in USA: 1988



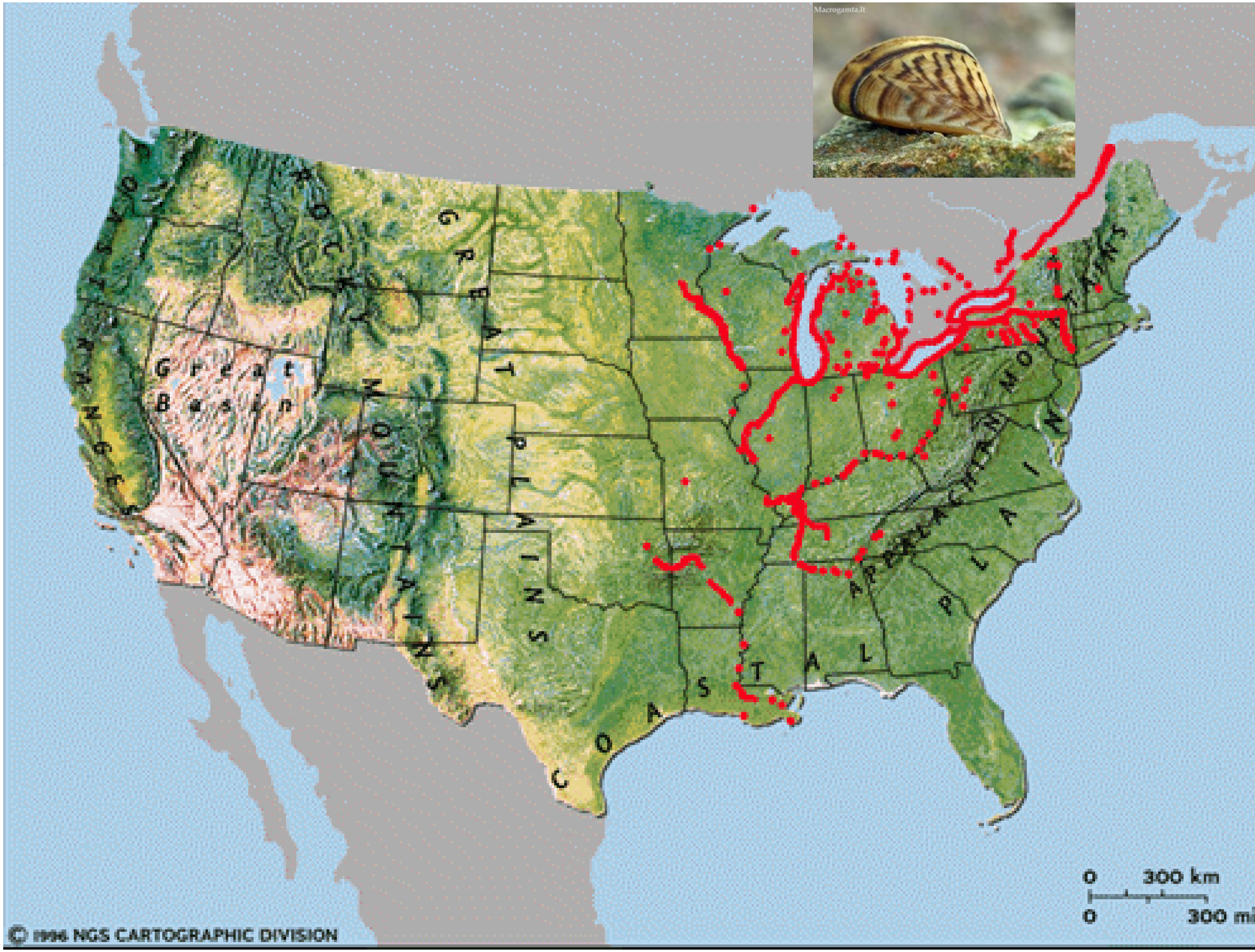
Zebra Mussel Spread in USA: 1990



Zebra Mussel Spread in USA: 1992

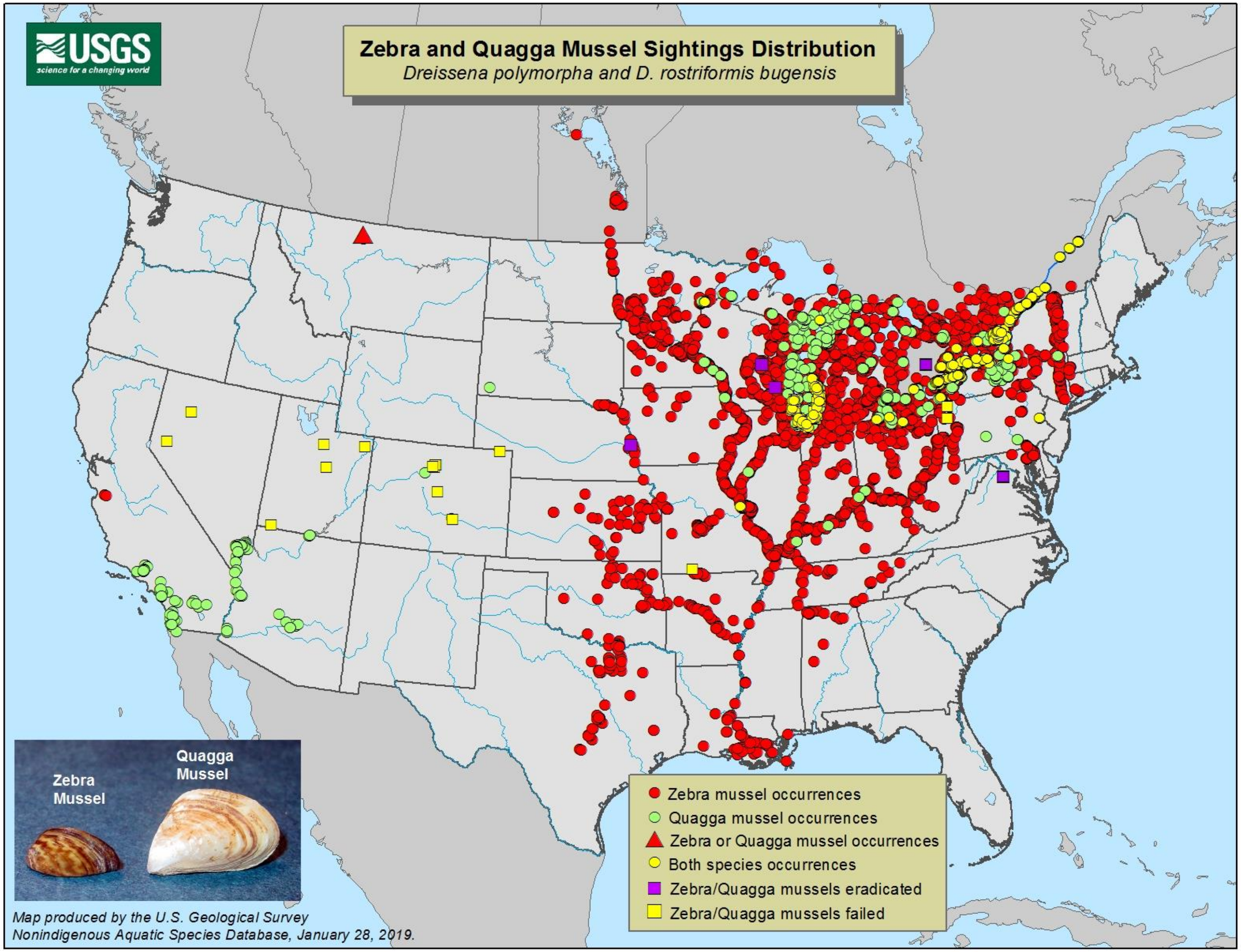


Zebra Mussel Spread in USA: 1995



Zebra Mussel Spread in USA: 2002

Dreissena Spread in USA: 2019



Zebra Mussel in USA vs. Europe: **Early Invasion**

- Zebra mussels spread quickly across the whole US, creating fear that soon all inland lakes will be invaded
- Zebra mussels density in America are much higher than in Europe
- Zebra mussels impact in North America is much stronger than in Europe
- European experience is not particularly valuable
- Zebra mussel was declared the most aggressive freshwater invader and triggered **Executive Order** 13112 - **Invasive Species** signed by president Bill Clinton on February 3, 1999

Zebra Mussel in USA vs. Europe: **Current Situation**

- Zebra mussels spread quickly across the whole US, creating fear that soon all inland lakes will be invaded – Although dreissenids quickly spread over USA, their rate of colonization of inland lakes was very slow. In Wisconsin, after >20 years of invasion, only 120 of >15,000 inland lakes (<1%) were invaded by 2013
- Zebra mussels density in America are much higher than in Europe – Methodological problems + The density is higher on the initial stage of invasion (all US) than later in the invasion (most of Europe)
- Zebra mussels economic and ecological impact in North America is much stronger than in Europe – The impact was to some extent exaggerated + The impact is stronger on the initial stage of invasion (all US) than later in the invasion (most of Europe)
- European experience is not particularly valuable – largely due to the language barrier – **publish in English!**

Zebra vs. Quagga Mussels: Could we Predict their Population Dynamics?

- Recent study summarizing long-term data sets on dreissenids from 67 different sites in Europe and North America conclude that these data are insufficient to meet research and management needs **<u>likely due to different methods and sampling designs</u>** *(Strayer et al. 2019)*
- More consistent sampling design employed on Great Lakes, however, can offer some insights into *Dreissena* population dynamics

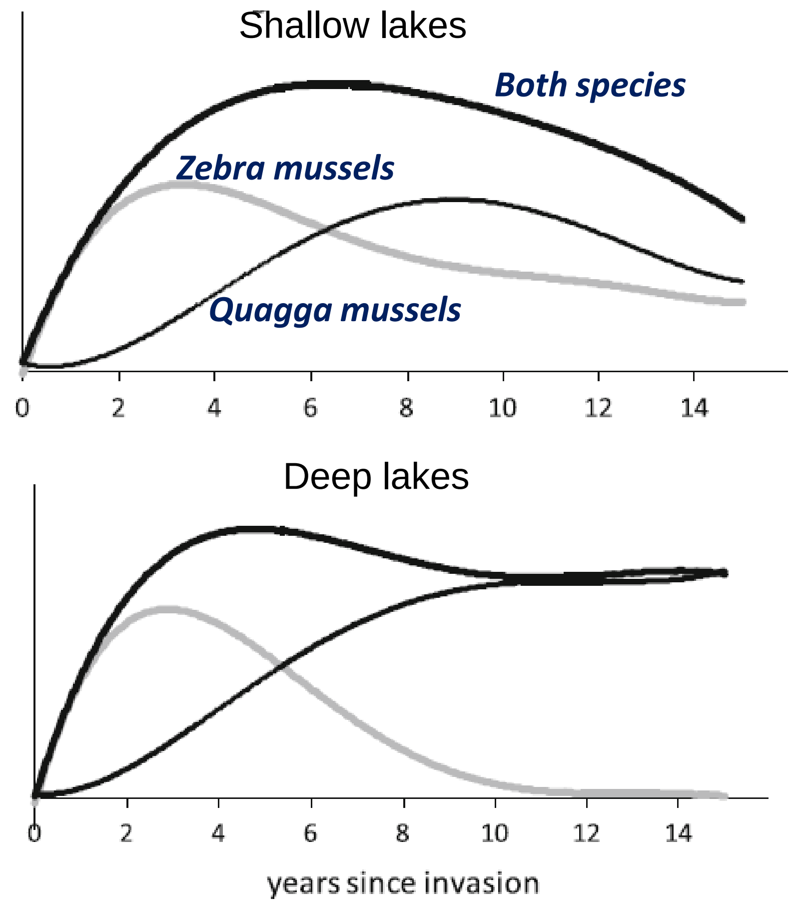
esa ECOSPHERE

Long-term population dynamics of dreissenid mussels (*Dreissena polymorpha* and *D. rostriformis*): a cross-system analysis

David L. Strayer,[1,2,3,†] Boris V. Adamovich,[4] Rita Adrian,[3,5] David C. Aldridge,[6] Csilla Balogh,[7,8] Lyubov E. Burlakova,[9] Hannah B. Fried-Petersen,[10] László G.-Tóth,[7,11] Amy L. Hetherington,[12] Thomas S. Jones,[13] Alexander Y. Karatayev,[9] Jacqueline B. Madill,[14] Oleg A. Makarevich,[4] J. Ellen Marsden,[15] André L. Martel,[14] Dan Minchin,[16,17] Thomas F. Nalepa,[2] Ruurd Noordhuis,[18] Timothy J. Robinson,[19] Lars G. Rudstam,[20] Astrid N. Schwalb,[21] David R. Smith,[22] Alan D. Steinman,[23] and Jonathan M. Jeschke[3,5,24]

Hypotheses Addressed:

1. Zebra and quagga mussel population dynamics across deep Great Lakes will be similar, but will differ from shallow lakes
2. Zebra and quagga mussel will co-exist in shallow, but not in deep lakes
3. Replacement of zebra with quagga mussels in deep lakes maybe associated with a large increase in the lake-wide dreissenid density



Hydrobiologia (2015) 746:97–112
DOI 10.1007/s10750-014-1901-x

INVASIVE SPECIES — Review Paper

Zebra versus quagga mussels: a review of their spread, population dynamics, and ecosystem impacts

Alexander Y. Karatayev · Lyubov E. Burlakova · Dianna K. Padilla

Great Lakes are the only large freshwater ecosystem in the world that have:

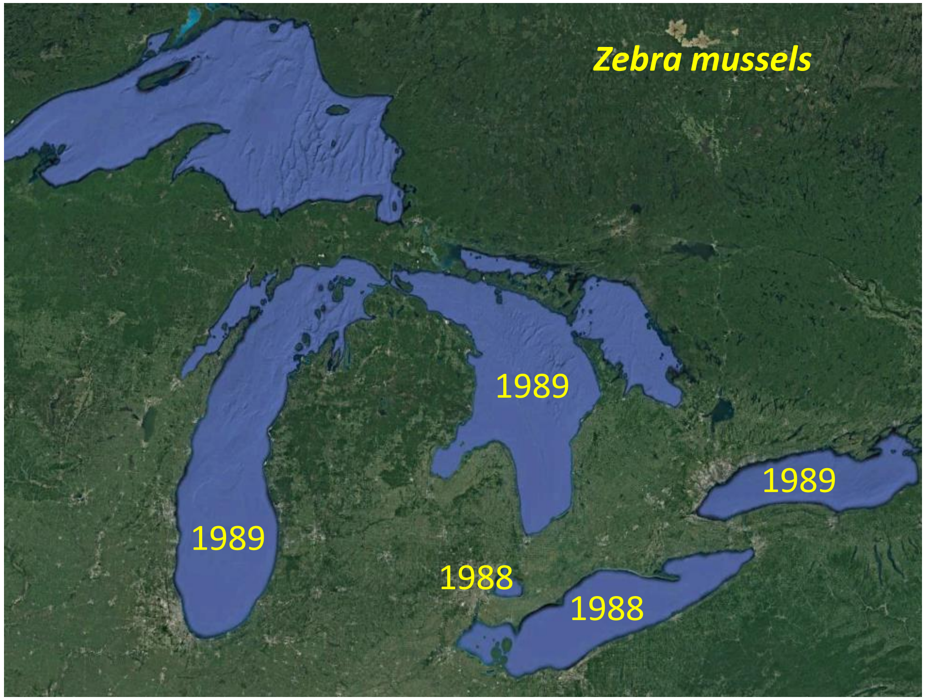
1. large environmental gradients (from shallow to very deep and from eutrophic to oligotrophic)
2. colonized by both *Dreissena* species
3. have long-term data on *Dreissena* population dynamics
4. good pre-invasion data

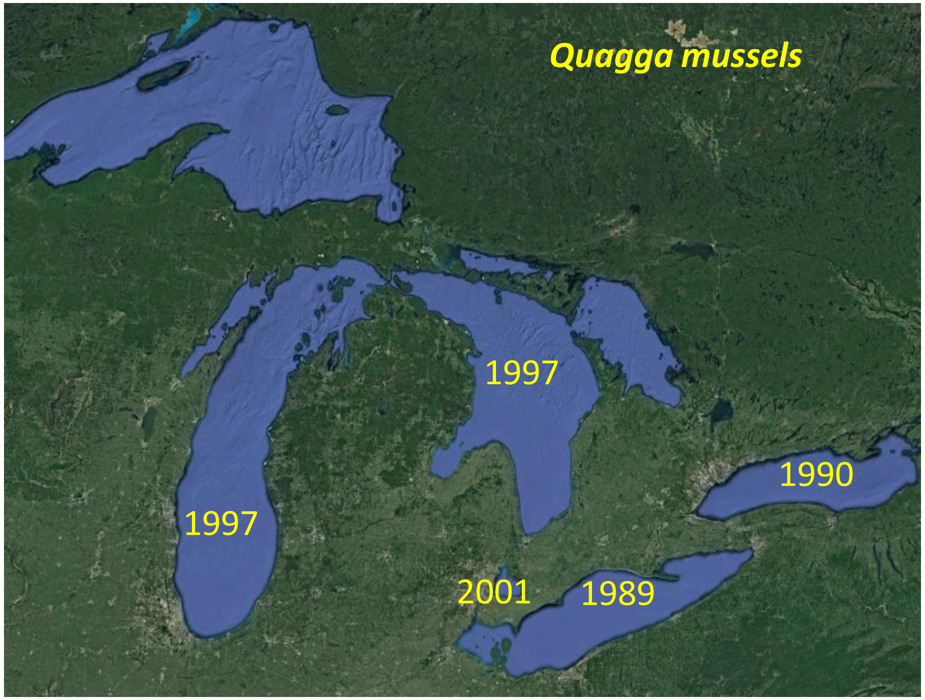
Lake	Surface, km^2	Volume, km^3	Maximum depth, m	Average depth, m	Proportion of the bottom > 30 m, %
Shallow					
St. Clair	1113	3.4	6.4	3.0	0
Saginaw Bay	2770	24.5	13.7	8.9	0
Erie, western basin	3680	28.0	19	7.6	0
Deep					
Ontario	18960	1631	244	86	78.4
Michigan, main basin	53537	4846.0	282	90.5	77.6
Huron, main basin	43086	2 842.0	229	66	79.1

Spread across Great Lakes

- Zebra mussels were found in 1988 in lakes Erie and St. Clair, and in two years colonized all Great Lakes *(Hebert et al.1989; Griffiths et al. 1991; Nalepa et al. 2001)*
- For quagga mussels it took four times longer (8 vs. 2 years) to spread across all Great Lakes *(Griffiths et al. 1991; Mills et al. 1993; Nalepa et al. 2001)*

All lakes were originally colonized by zebra and only later by quagga mussels





Time since invasion

The lag time between when mussels were first detected in a waterbody and when they reached high population density was much longer for quagga than for zebra mussels (**9 – 15** vs. **2 – 4** years)

Therefore, initially all lakes were dominated by zebra mussels

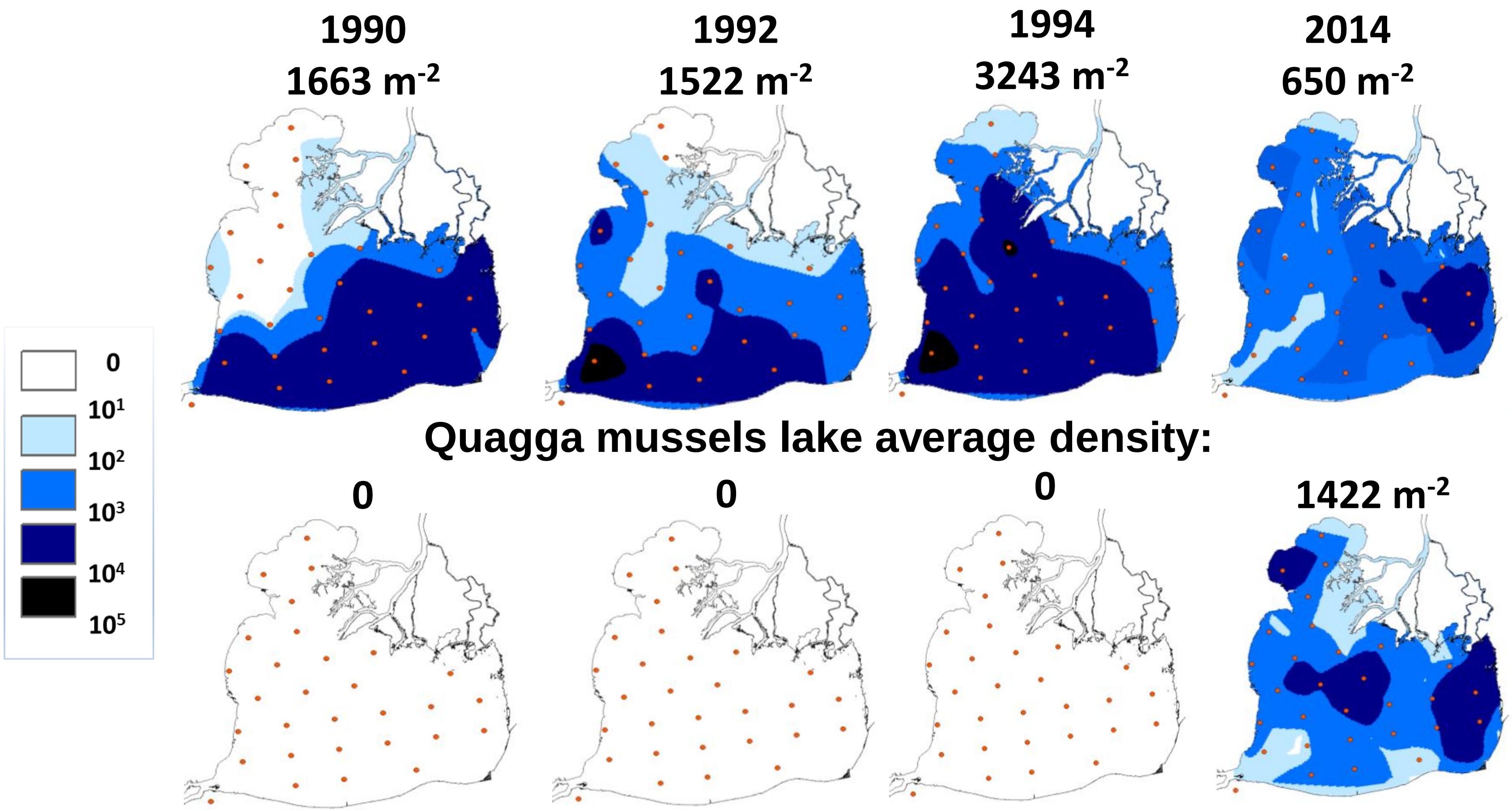
Time between first mussels detection and when they reached population maximum

Lake	*Zebra mussels*	*Quagga mussels*
Erie, eastern basin	**2**	**9**
Erie, western basin	**2**	**15**
Ontario	**3**	**13**
Michigan	**4**	**13**
Huron, main basin	No data	**15**
Huron, Saginaw Bay	**2**	No data
St Clair	**2**	No data
AVERAGE	**2.5**	**13.0**

Shallow lakes: Lake St. Clair (average depth 3 m)

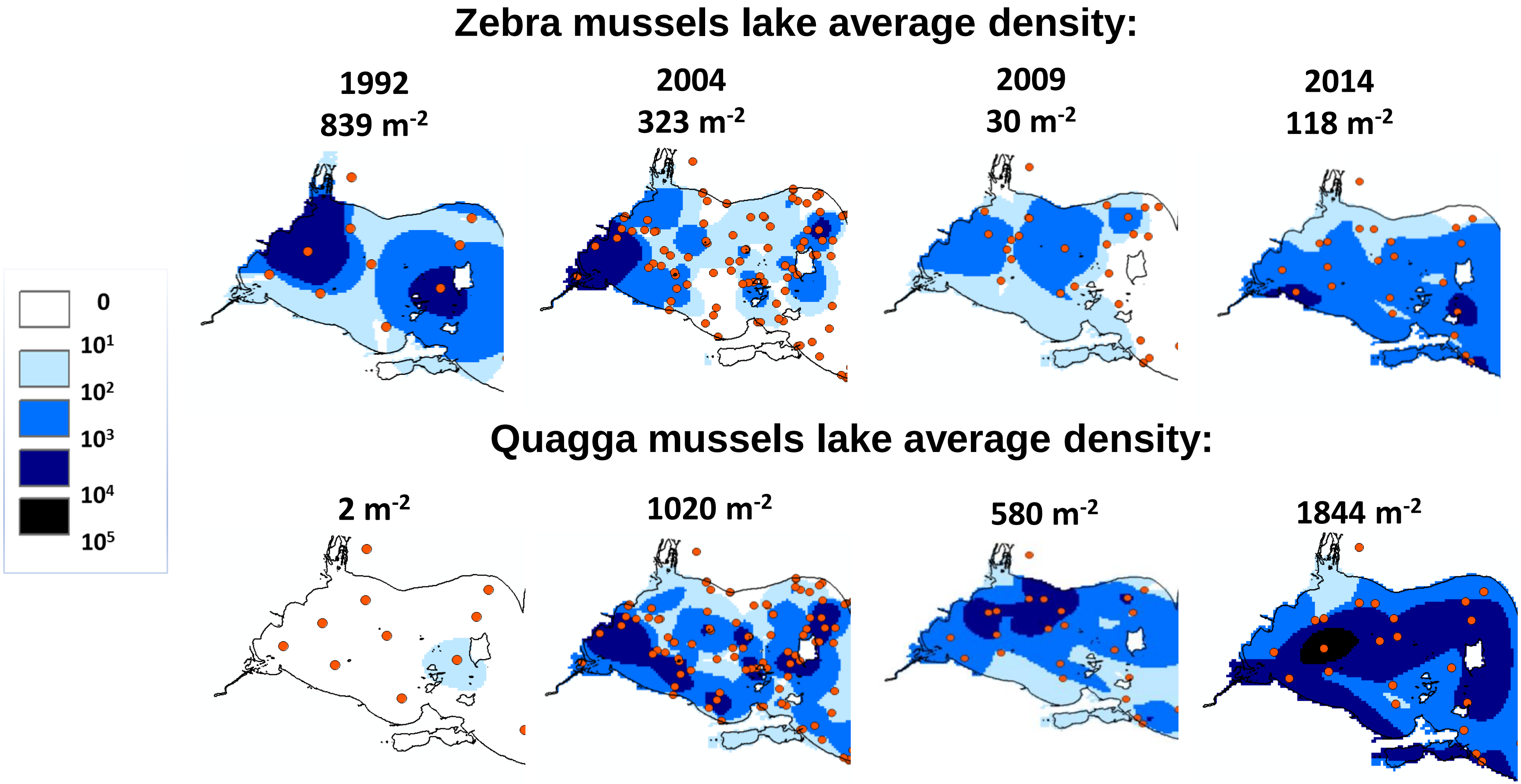
- Zebra mussels colonized lake in 1988 and quagga mussels in 2001
- By 2014 quagga became dominant, but zebra mussels still common and their combine density in 2014 was similar to 1990s, when the lake was colonized by zebra mussel alone
- Both dreissenid species colonized the entire lake

Zebra mussels lake average density:



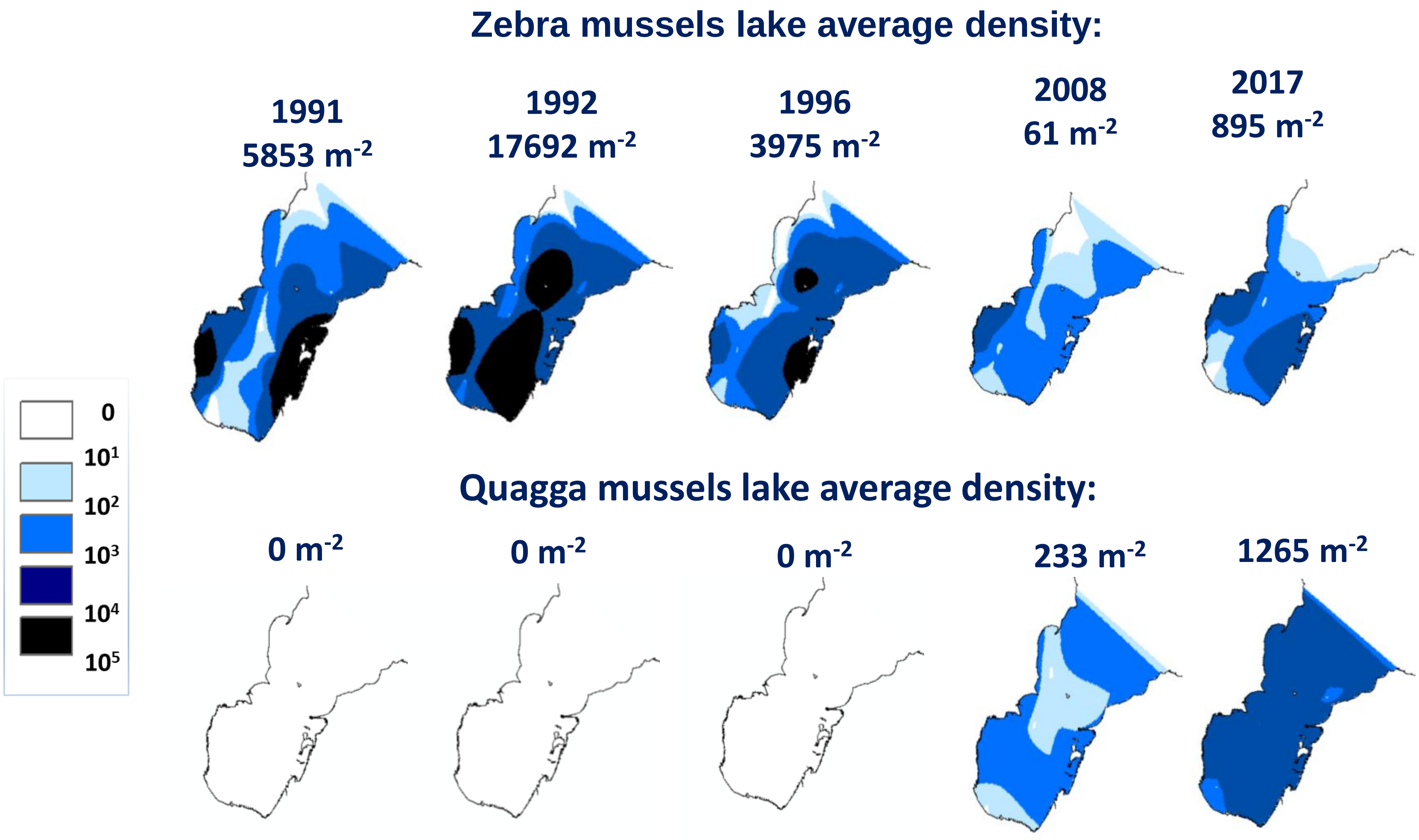
Shallow Lakes: Lake Erie, WB (average depth 7.6 m)

- After 8 years of coexistence, quagga became dominant, but zebra mussels still common and the combined density of both species in 2014 was only 2.5 times higher than zebra mussels alone in 1992
- Both dreissenid species colonized the entire lake



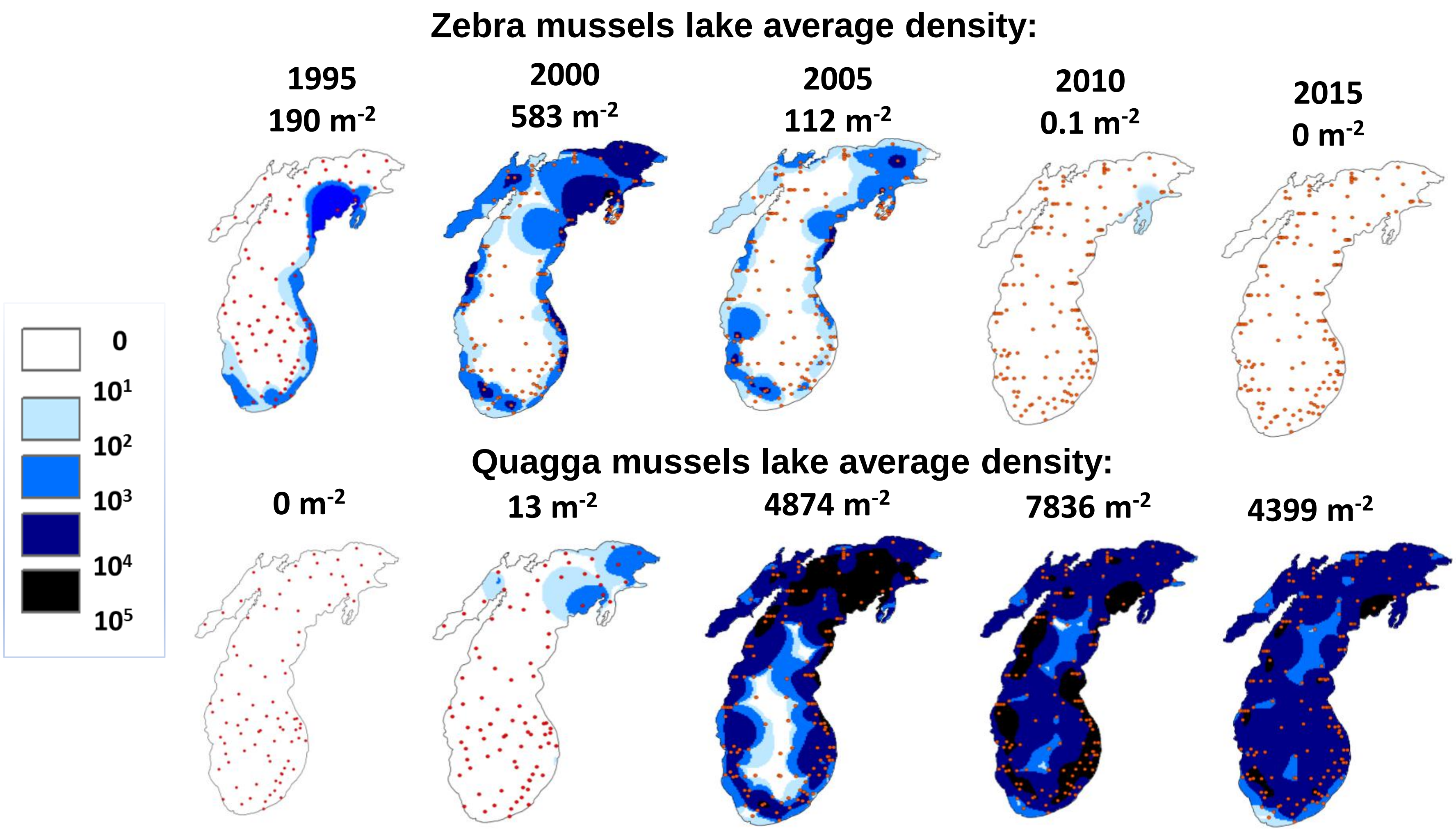
Shallow Lakes: Saginaw Bay (average depth 8.9 m)

- By 2008 quagga became dominant, but zebra mussels still common and their combine density in 2017 was 1.8 times lower than in 1996, when the lake was colonized by zebra mussel alone
- Both dreissenid species colonized the entire lake



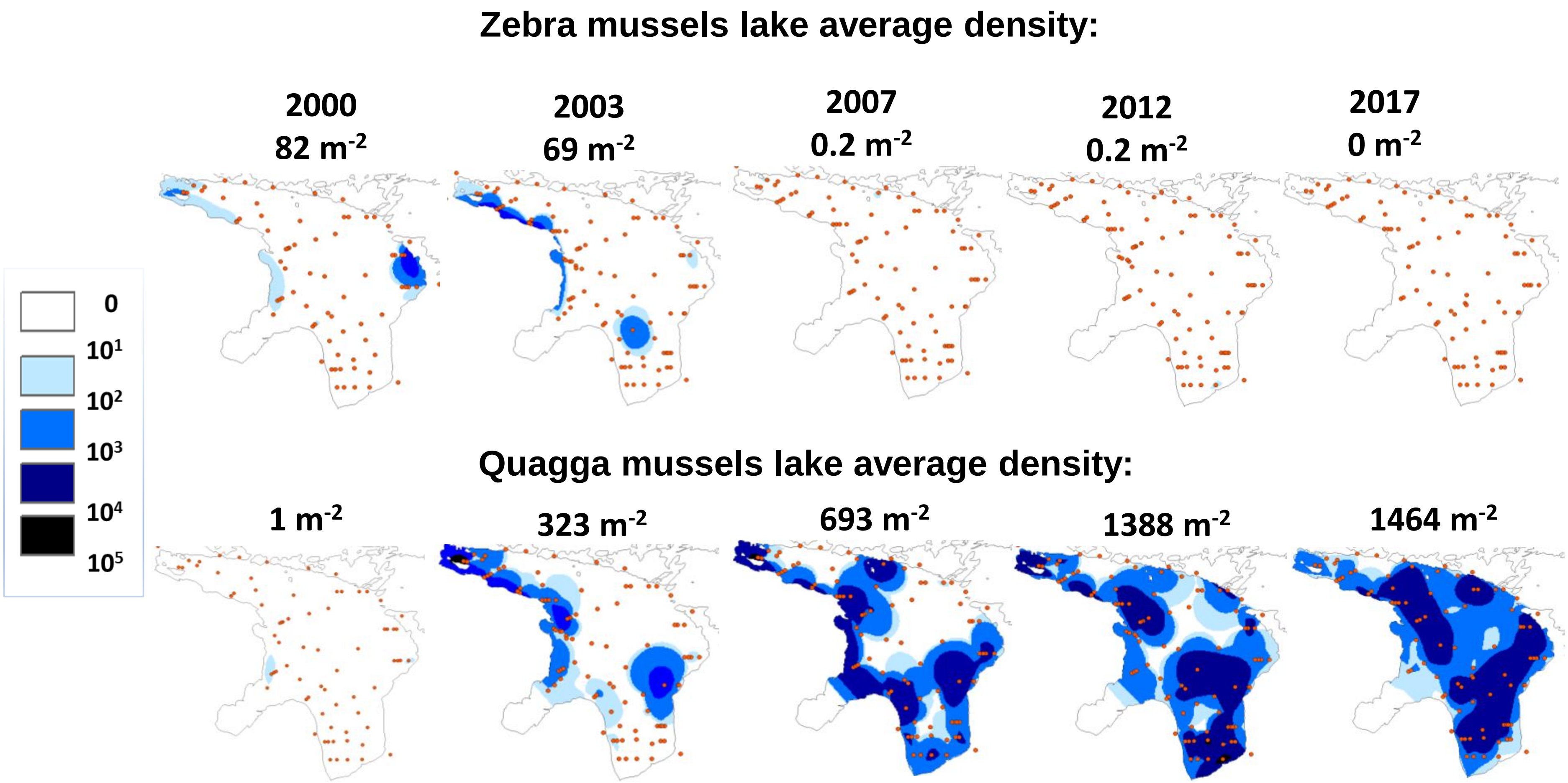
Deep Lakes: Lake Michigan (average depth 91 m)

- Quagga outcompeted zebra mussels in ~ **8** years and created lake average densities > **13** times higher than that of zebra mussels during their maximum population density
- While zebra were limited to nearshore areas, quagga mussels colonized the whole bottom



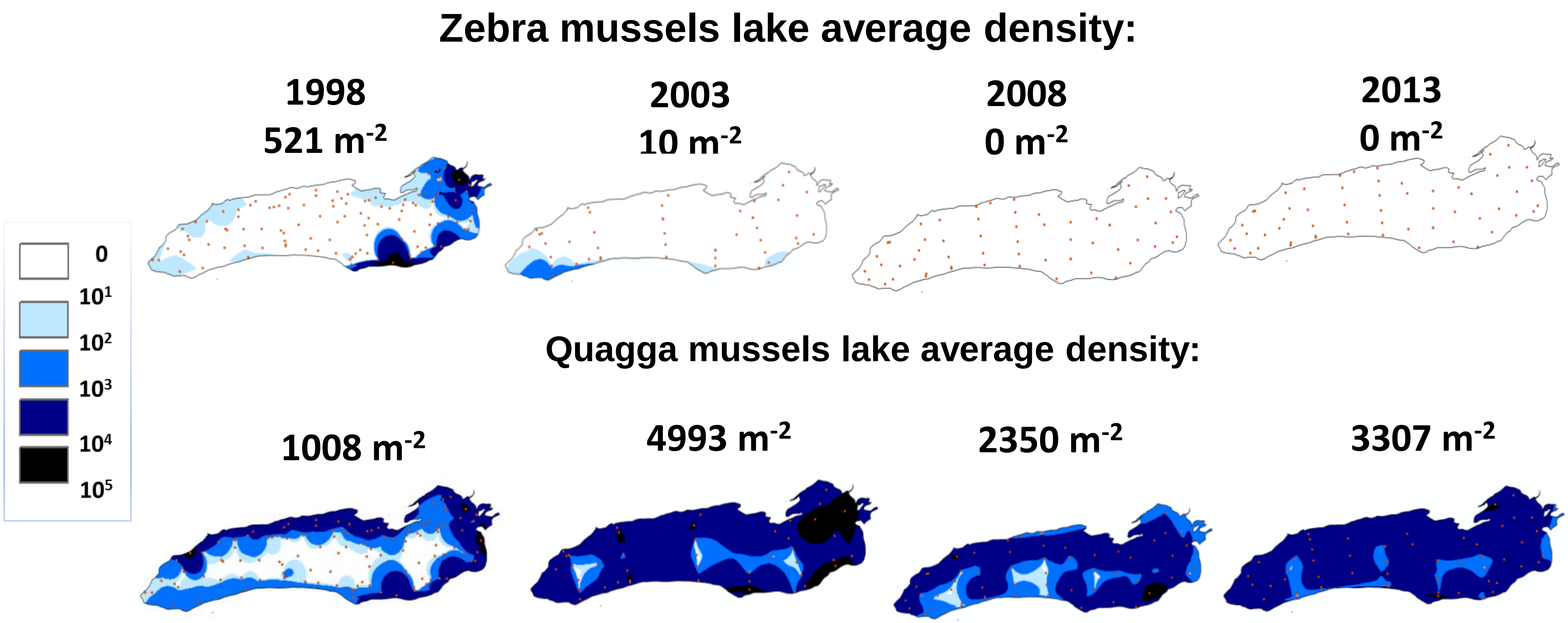
Deep Lakes: Lake Huron (average depth 66 m)

- Quagga outcompeted zebra mussels in ~ **6** years and created lake average densities > **17** times higher than that of zebra mussels during their maximum population density
- While zebra were limited to nearshore areas, quagga mussels colonized the whole bottom



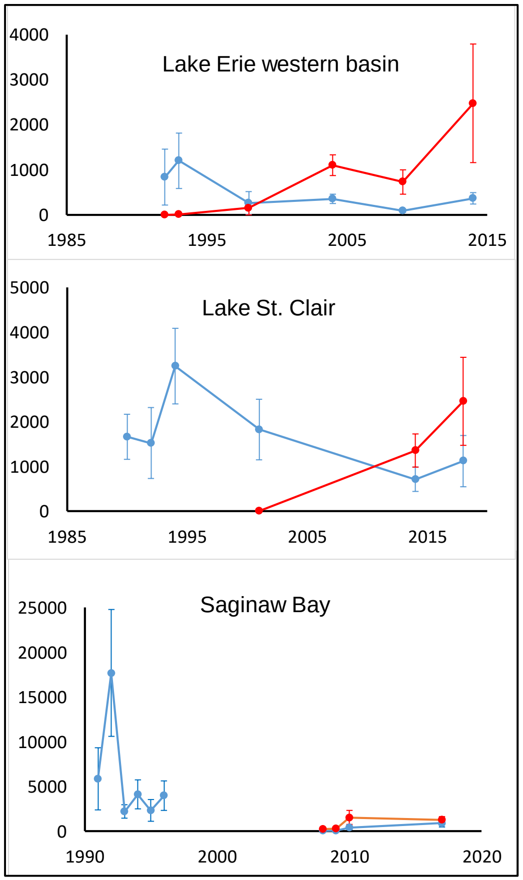
Deep lakes: Lake Ontario (average depth 86 m)

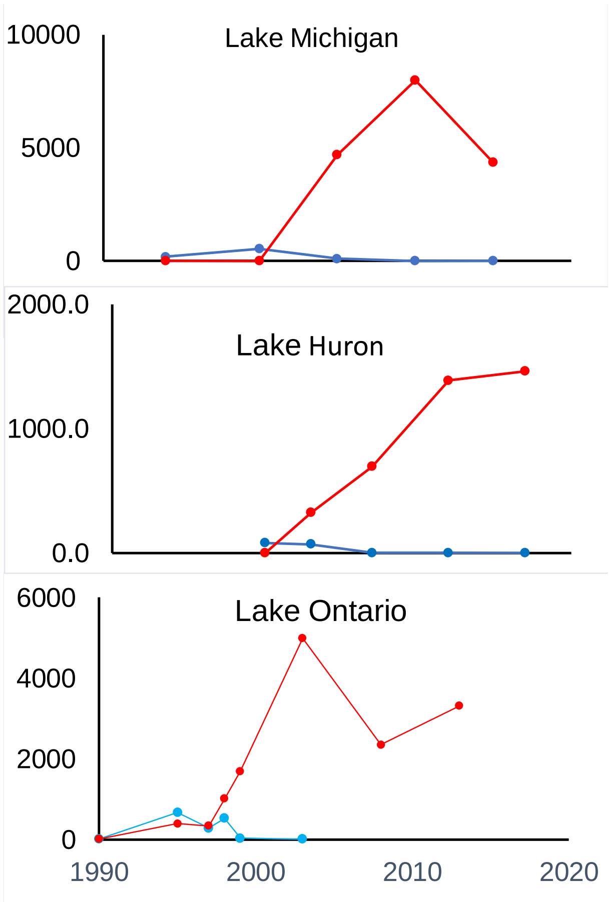
- Quagga outcompeted zebra mussels in **~ 7** years and created lake average densities **10** times higher than that of zebra mussels during their maximum population density
- While zebra were limited to nearshore areas, quagga mussels colonized the whole bottom



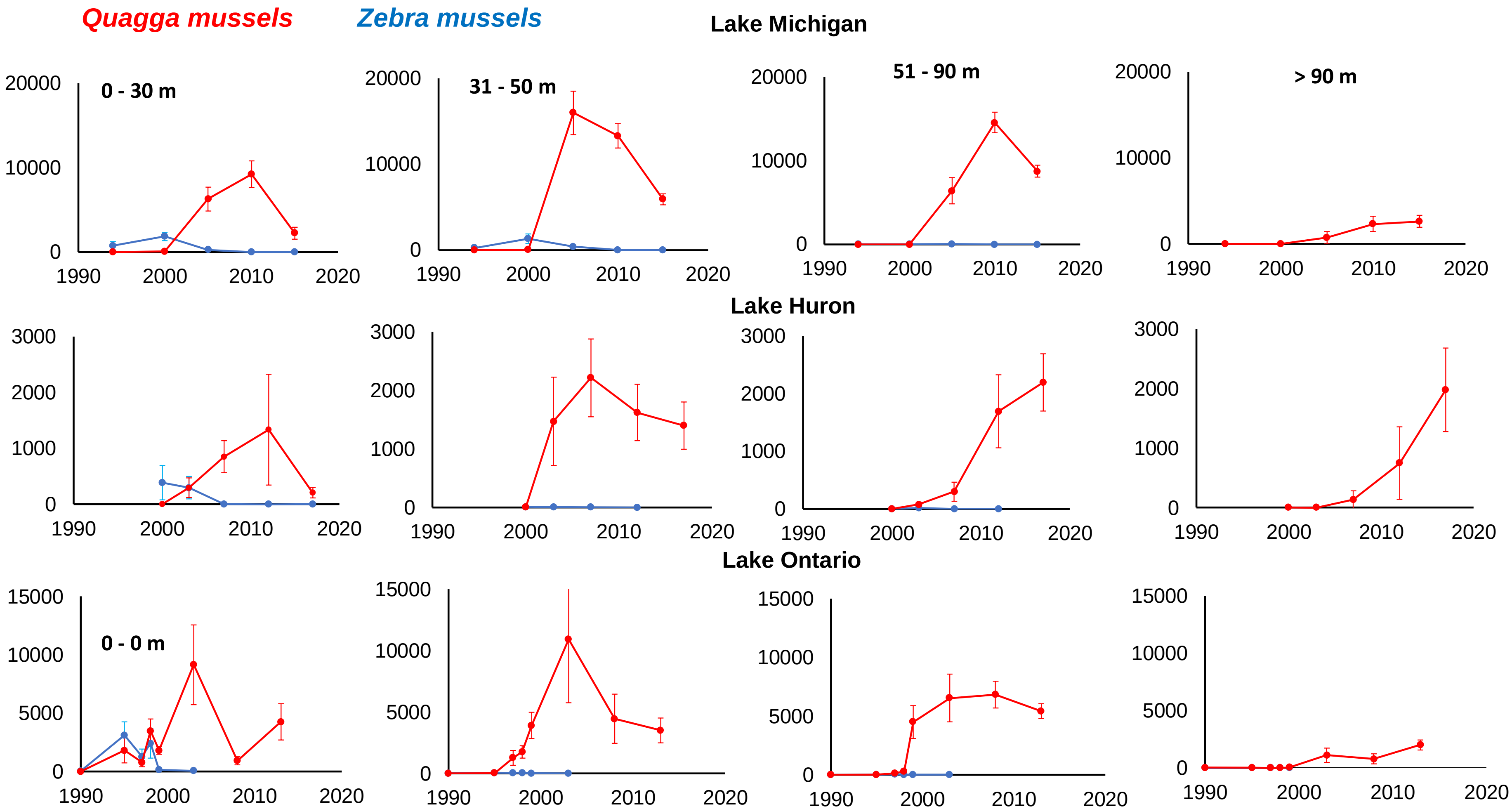
Population Dynamics in Shallow vs. Deep Lakes

- **Shallow Lakes:** After 8 – 12 years of coexistence quagga mussels became dominant, however zebra mussels remain common
- **Similar to shallow, in deep lakes** quagga mussels became dominant after 6 - 8 years of coexistence with zebra mussels
- **In contrast to shallow, in deep lakes** there was virtually complete displacement of zebra with quagga mussels and dramatic increase in lake-wide dreissenid density





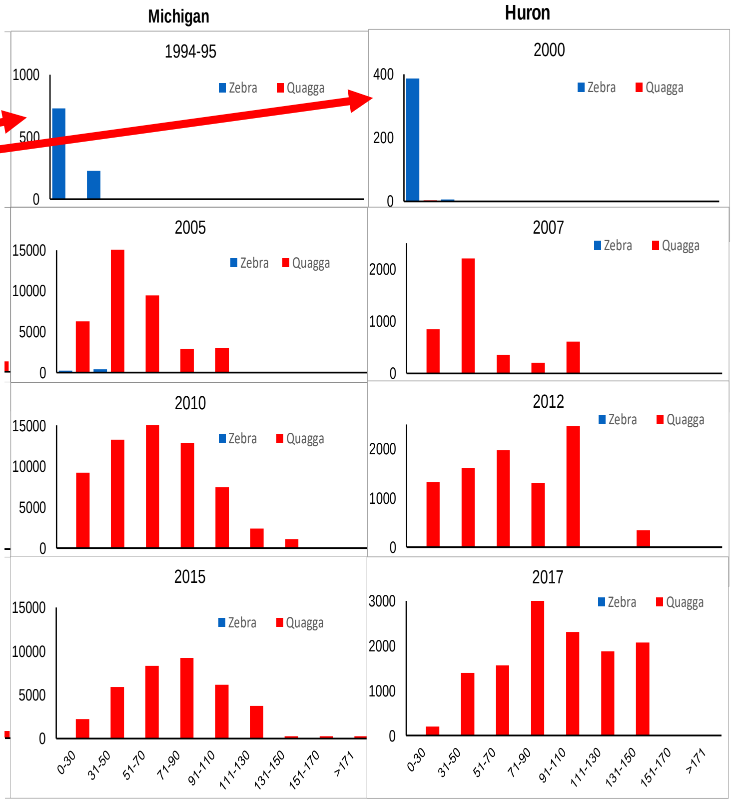
Population Dynamics: Deep Lakes

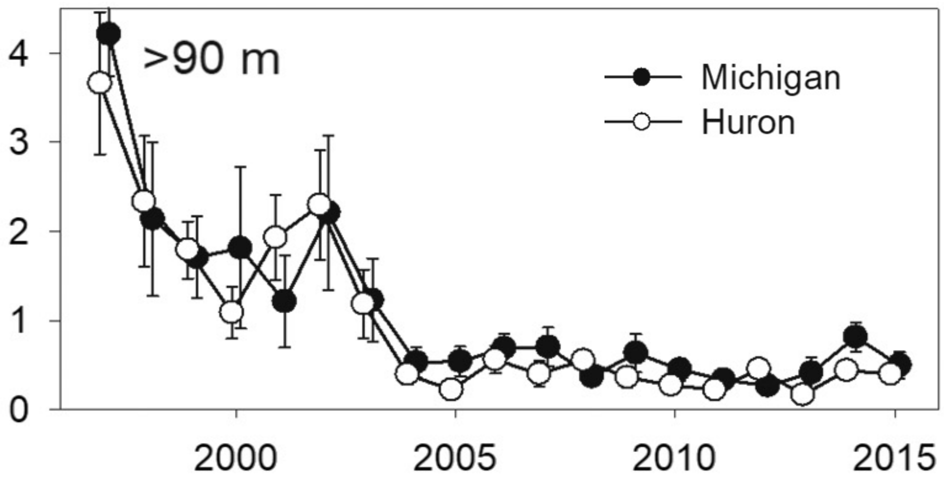


- 12 – 15 years after the first detection, *Dreissena* have reached their carrying capacity in shallow to mid depth range, and are declining
- The lake-wide decline is accompanied by a shift of mussel density toward deeper areas
- The patterns are remarkably similar in all lakes

Dreissena Distribution: Nearshore Shunt

- Early in the invasion lakes were colonized by *D. polymorpha* alone and mussels were largely limited to the shallow (< 30 m) nearshore zone
- Communities were strongly affected by zebra mussels but the impact was limited to shallow areas
- Dreissenids retain P & C at the expense of the offshore communities **"nearshore phosphorous shunt"** (*Hecky et al. 2004*).
- Effect on profundal and epilimnetic communities was remote (e.g. decline in *Diporeia* in the profundal before these areas were colonized with dreissenid)





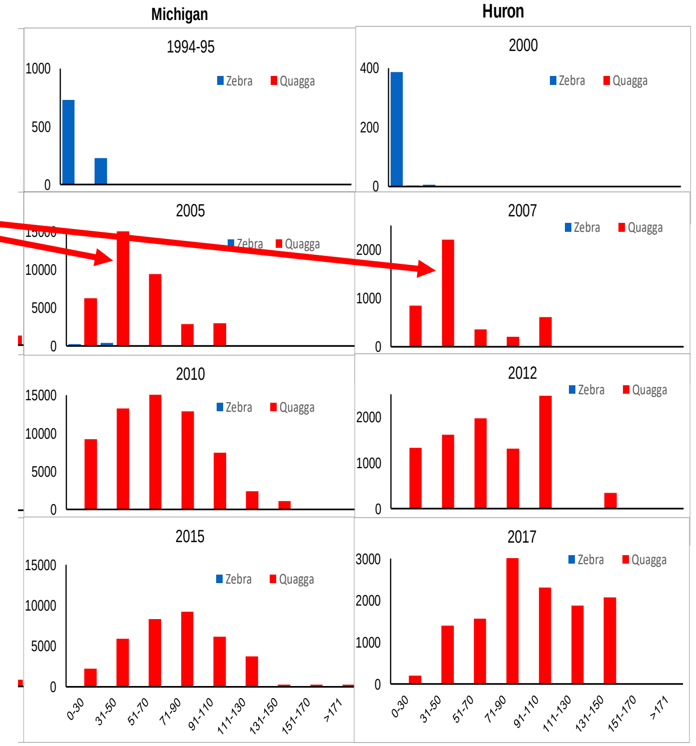
Dynamics of *Diporeia* in the profundal zone of lakes Michigan & Huron (*Barbiero et al. 2018)*

Dreissena Distribution: Mid 2010s, Mid-Depth C & P Sink

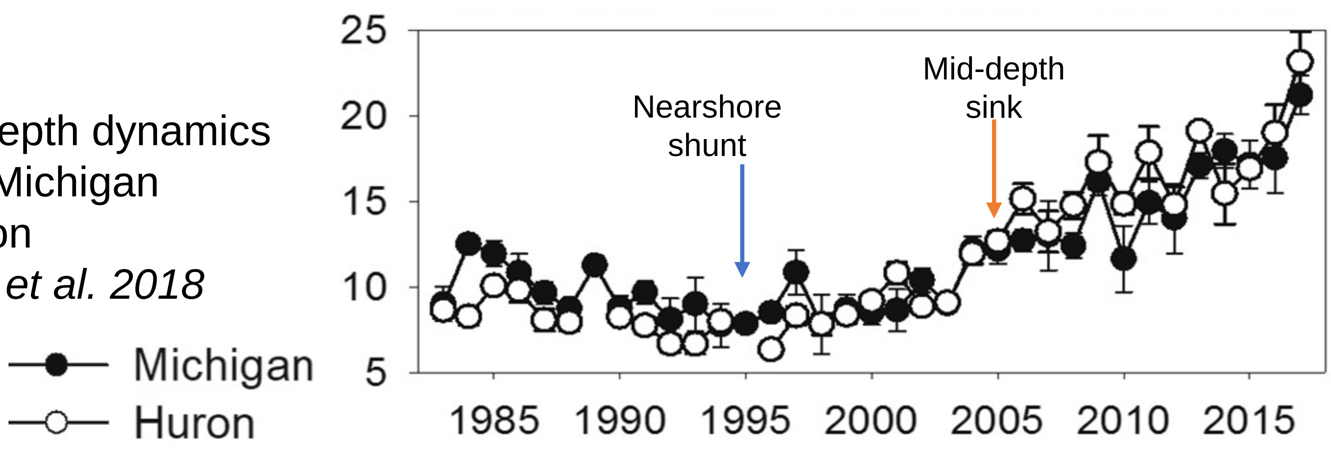
- The replacement of zebra with quagga mussels in mid 2000s was associated with the dramatic increase in density and biomass, and with the shift of the bulk of *Dreissena* spp. from the nearshore to 30 – 50 m

- Vanderploeg et al. (2010) estimated that *Dreissena* clearance rate per day in Michigan in the 30 – 50 m zone exceeded phytoplankton growth and suggested a **“mid-depth C & P sink“** hypothesis

- The explosion of quagga mussel population in mid-2000s was associated with the strongest changes in the offshore, including the increases in transparency and silica, decreases in seston, chlorophyll, etc. (reviewed in *Bunnell et al. 2014; Barbiero et al. 2018*)

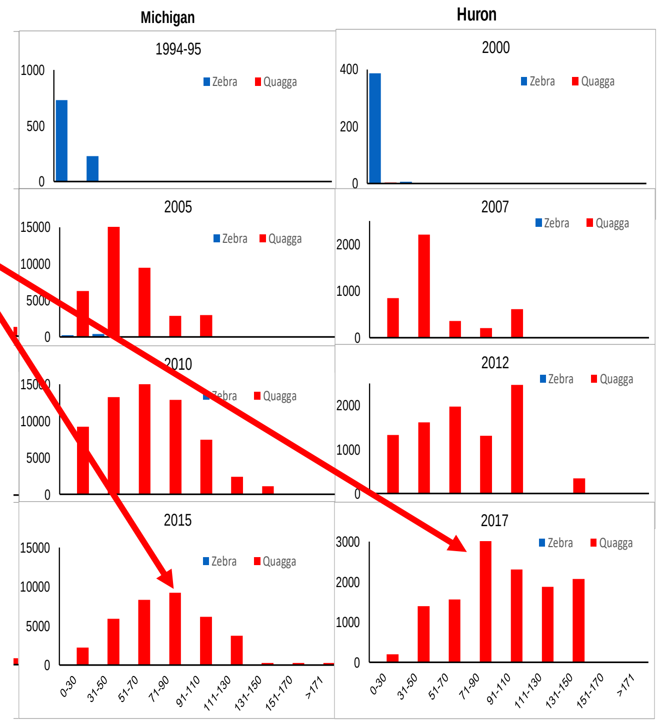


Secchi depth dynamics in lakes Michigan and Huron
Barbiero et al. 2018

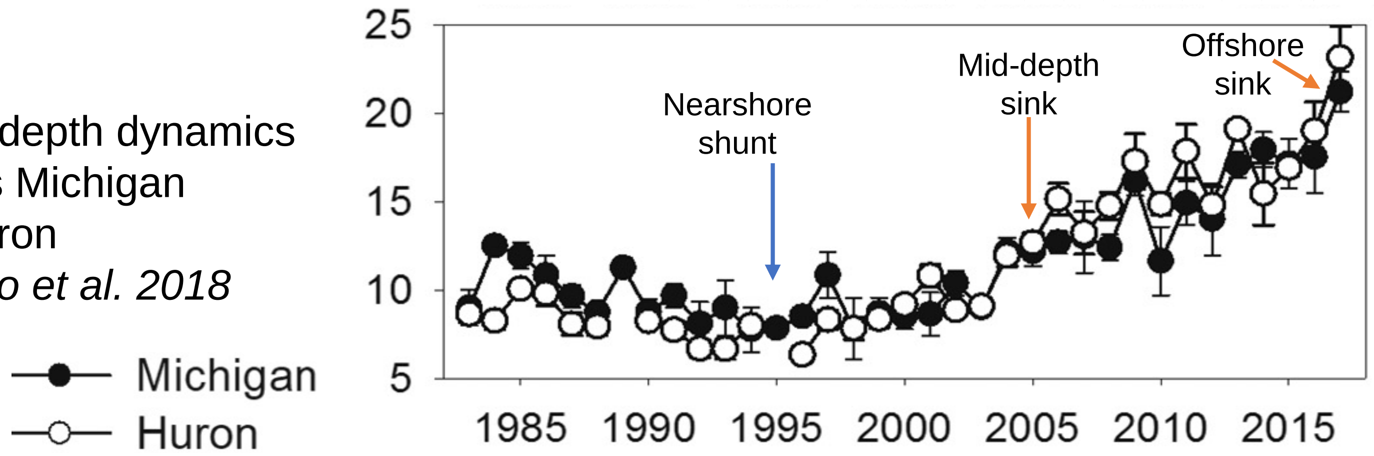


Current *Dreissena* Distribution: Offshore C & P Sink

- Although it was suggested (*Vanderploeg et al. 2010*) that further expansion of mussels into deep water will be constrained by the low phytoplankton productivity, recently the bulk of mussels has shifted much deeper (71-90 m)
- This shift was associated with a large decline of dreissenid density and biomass in the shallowest zone, and strong increase in deep-zone and lake-wide biomass
- We hypothesize that the shift of mussel population will likely continue to even deeper areas calling for further investigation to understand the ecosystem impact of this shift and suggest a new **“offshore C & P sink”** hypothesis

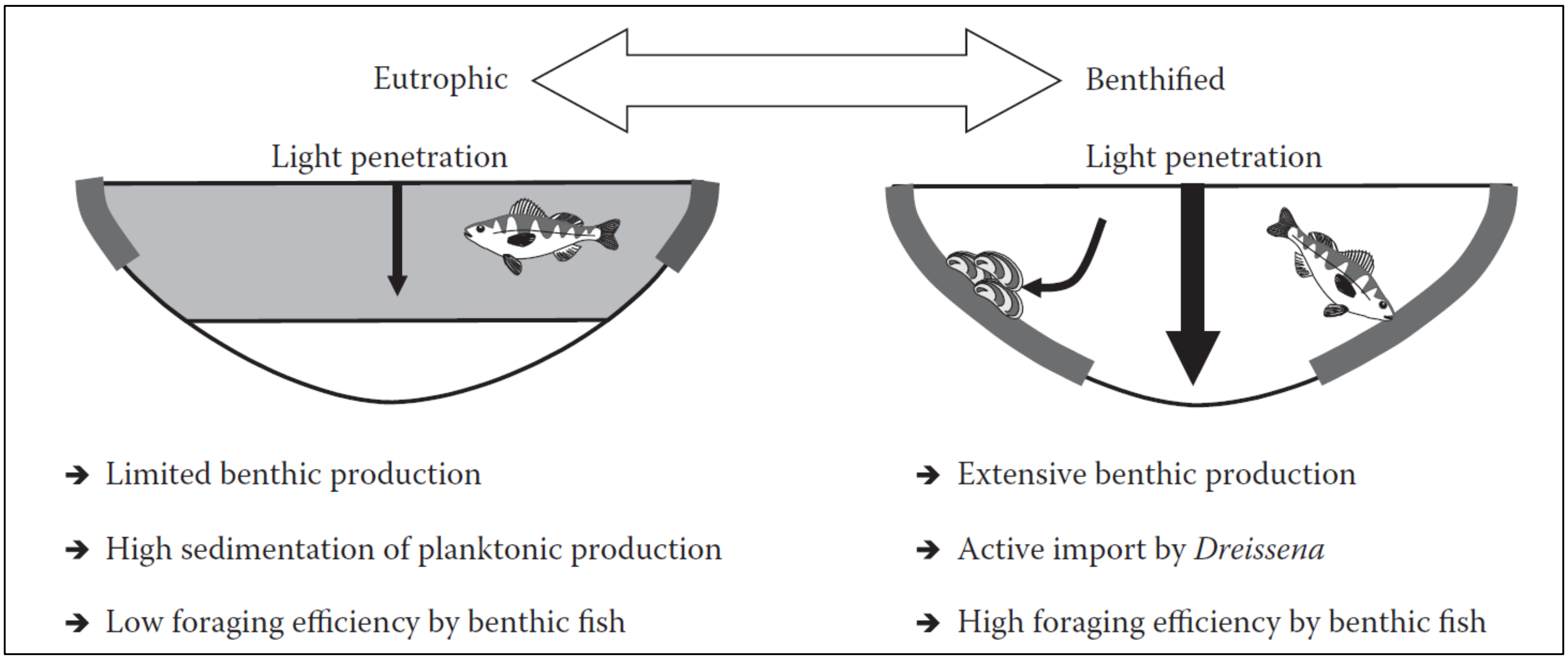


Secchi depth dynamics in lakes Michigan and Huron
Barbiero et al. 2018



Zebra vs. Quagga Mussels Ecological Impacts

- Dreissenids transfer materials from the water column to the benthos, providing a direct link between planktonic and benthic components of the ecosystem (benthic-pelagic coupling).
- This can trigger a suite of connected changes that increase the relative importance of the benthic community—a process sometimes referred to as **benthification** (Mayer et al., 2014).

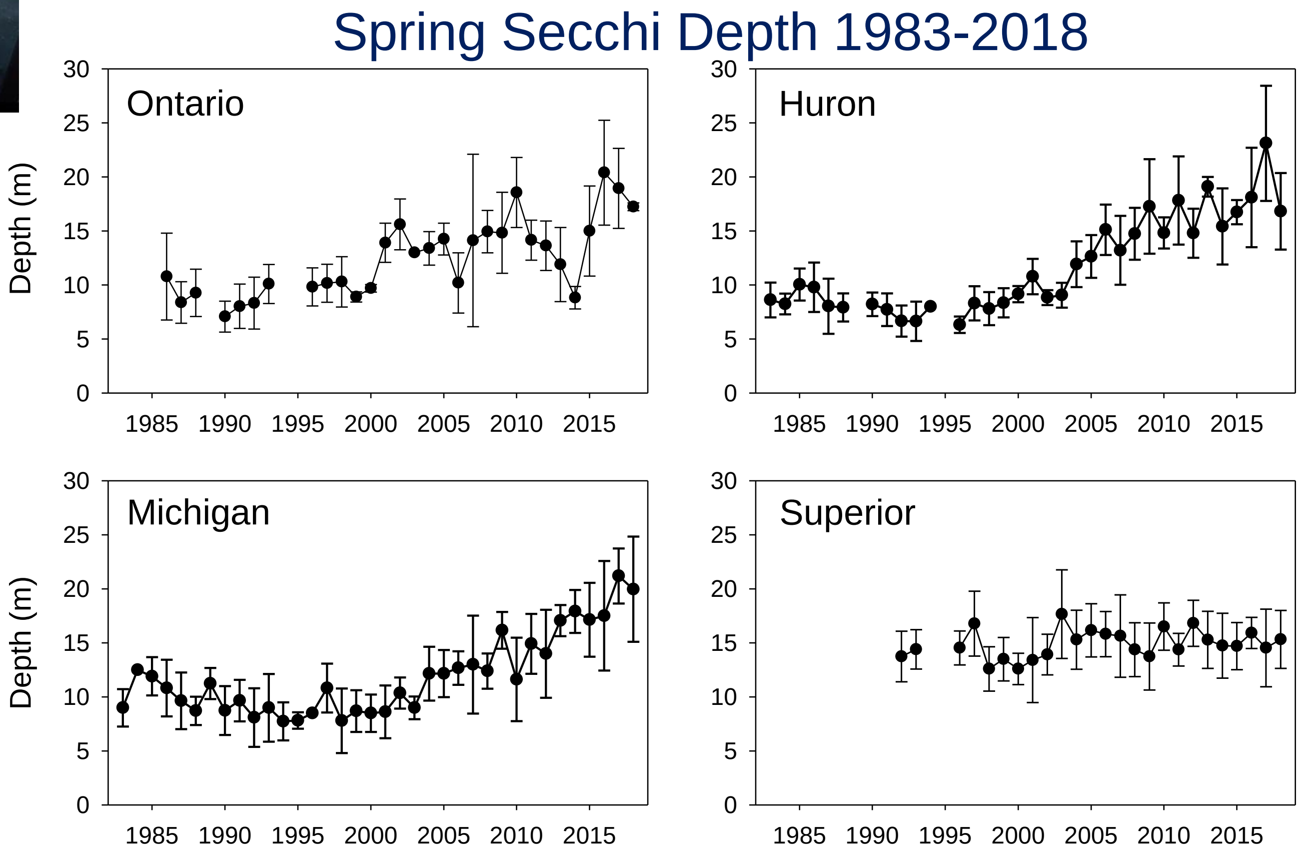


Zebra vs. Quagga Mussels Ecological Impacts

- Because quagga mussels have larger total population sizes they will filter larger volumes of water, and may have greater system-wide effects than zebra mussels in deep lakes
- However in the profundal zone, isolated from the epilimnion by the thermocline, the impact of quagga mussels on the water column may be lower than that of mussels in the well-mixed littoral zone
- In addition, because the clearance rate is temperature dependent, the filtering activity in the cold profundal zone should be less than that in the littoral zone

Zebra vs. Quagga Mussels Ecological Impacts

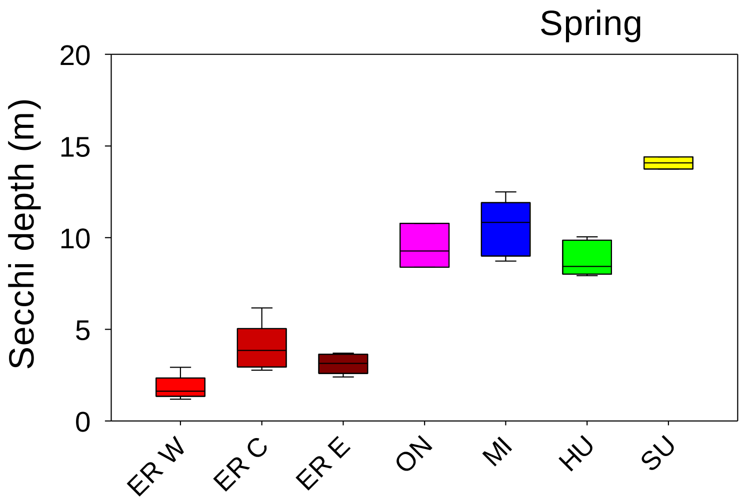
Increases in water clarity and light penetration, and decreases in turbidity, seston, and organic matter in the water column are among the most common and well documented impacts of zebra and quagga mussels on invaded waterbodies



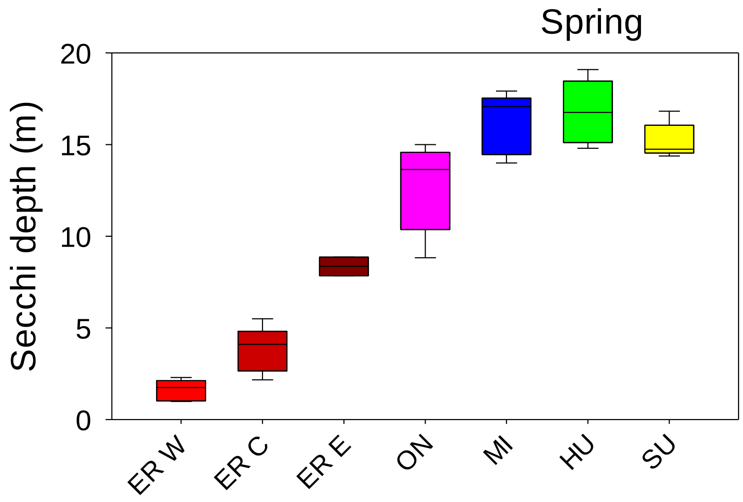
Zebra vs. Quagga Mussels Ecological Impacts

Increases in water clarity and light penetration, and decreases in turbidity, seston, and organic matter in the water column have cascading effect on the entire ecosystem including plankton, benthos and fish communities

Secchi depth before invasion



Secchi depth after invasion



Zoobenthos Long-Term Dynamics in the Great Lakes

First record of *D. bugensis*

EPA long-term monitoring sites

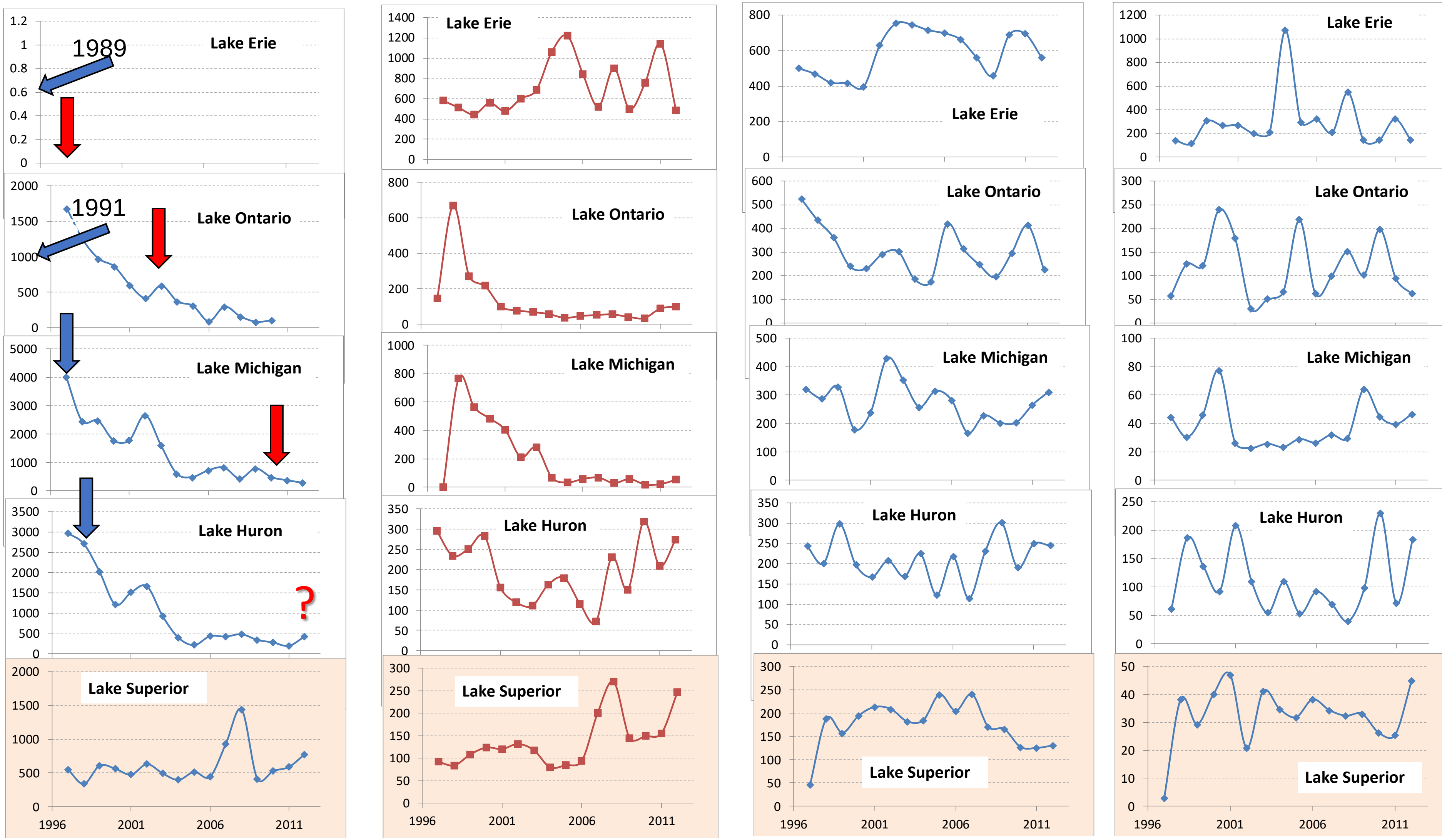
D. bugensis population maximum

***Diporeia* sp.**

Sphaeriidae

Oligochaeta

Chironomidae



Impact on Fish

- The introduction of quagga mussels in the profundal zone of Great Lakes is linked to the decline in whitefish through the dramatic decrease in their main food, the amphipod *Diporeia*
- Whitefish switch from *Diporeia* to quagga mussels. However, because of the lower energy content of mussels, this shift resulted in the decline of whitefish condition, growth, and abundance
- The decline in *Diporeia* is also associated with the decline of alewife, sculpin, bloater, and other fish that are prey for larger piscivores, including salmon and trout

Benthic video image analysis facilitates monitoring of *Dreissena*

Video vs. Bottom Grabs

- Almost every historical study of *Dreissena* in the Great Lakes has relied on bottom grabs with a small sampling area and small number of replicates
- The introduction of dreissenids, that create large well visible aggregations on lake bottom, made it possible to imply underwater remote sensing methods, commonly used in marine systems to study benthic sessile organisms

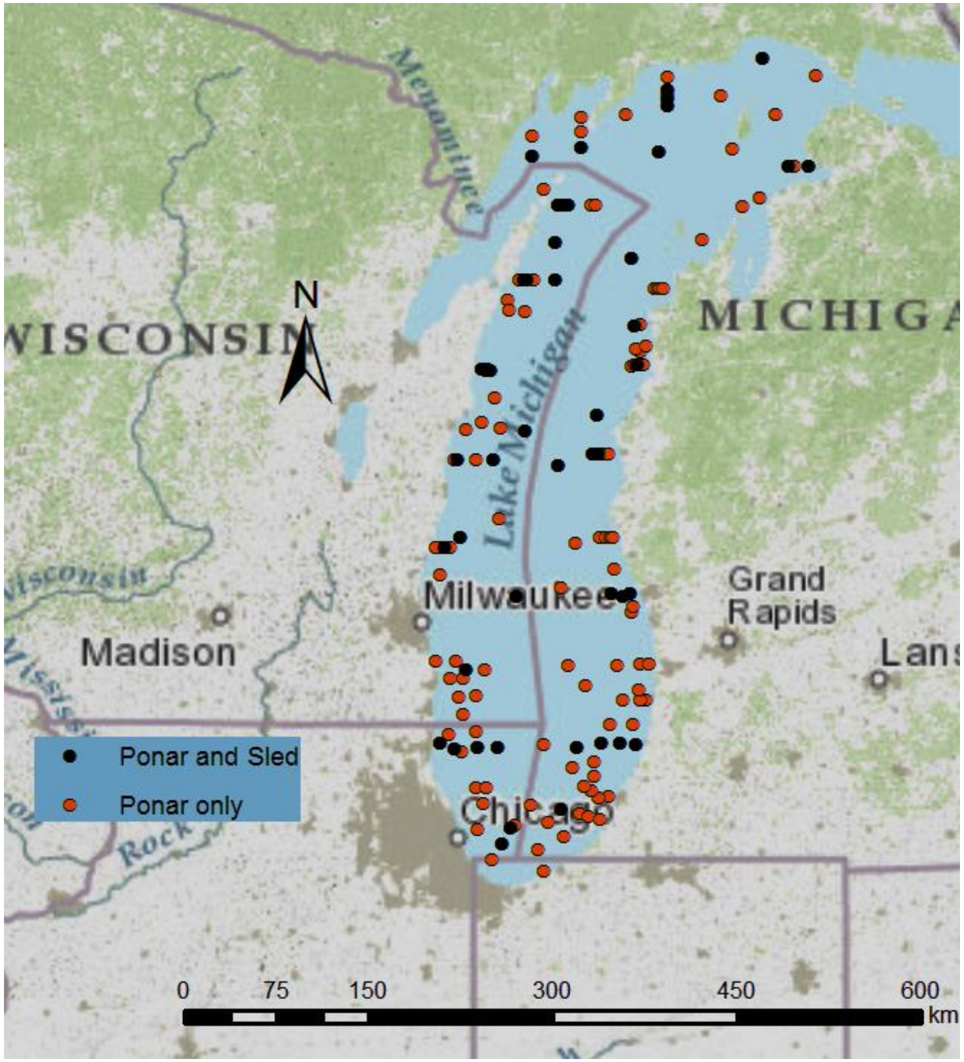


Implementation of remote sensing methods allows to:

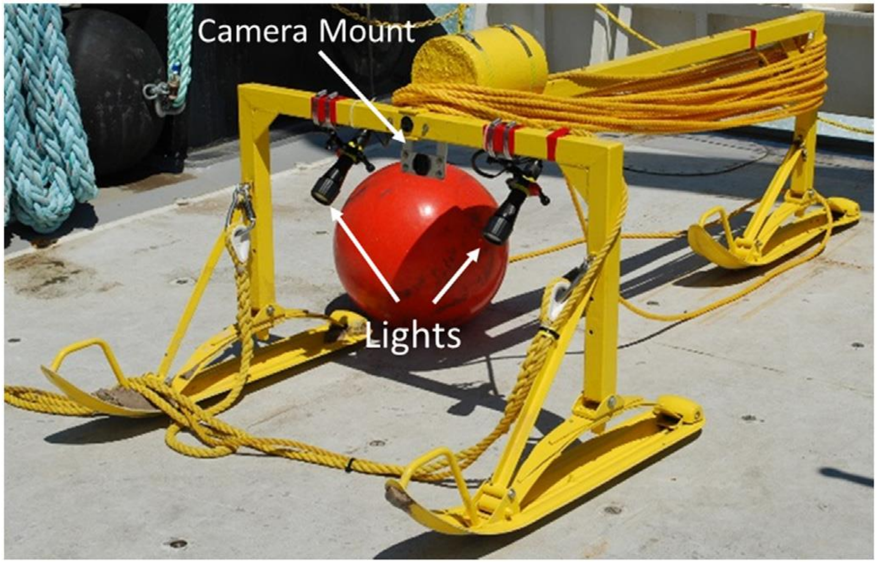
- survey much larger bottom areas than traditional bottom grabs or SCUBA
- study distribution patterns of *Dreissena* at various spatial scales
- improve the accuracy of estimation of mussels density

Lake Michigan 2015 CSMI

- 143 stations sampled
- 429 Ponar samples
- 616 video images attached to Ponar
- 47 benthic tows with GoPro camera



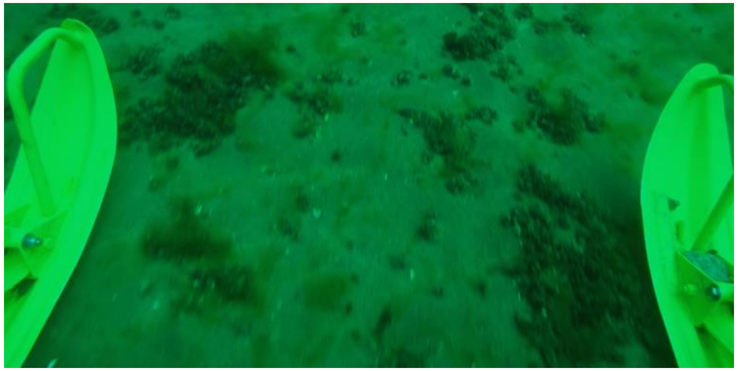
Old snowmobile



Lake Michigan 2015: Video Image Analysis

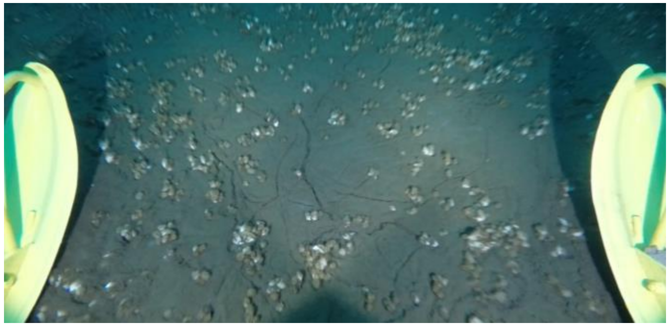
47 video transects were recorded with a GoPro camera mounted on a benthic sled towed behind the boat for 500 m

- 43 (92%) were used for analyses
- 4% not usable due to high turbidity and algae cover
- 4% not usable due to equipment malfunction

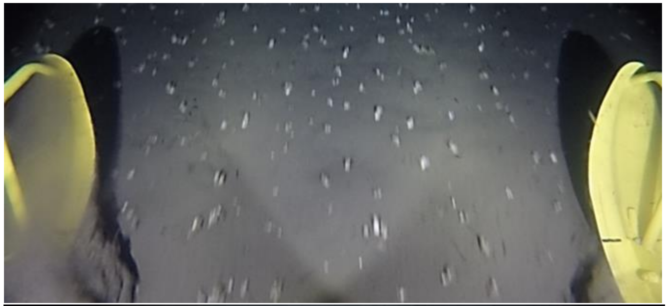


45 m

50 m



54 m



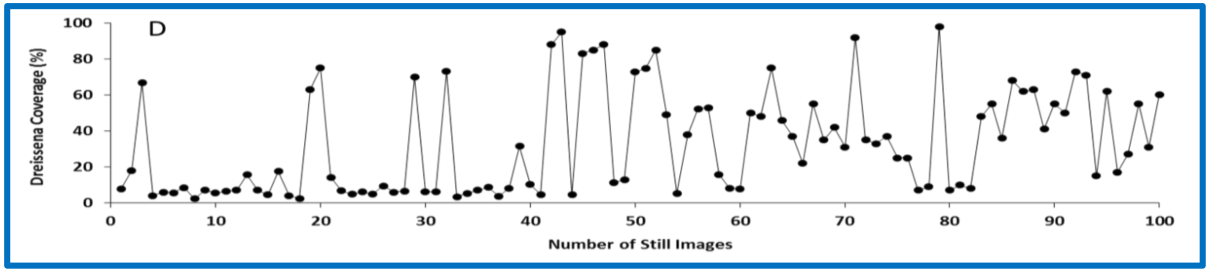
139 m

165 m

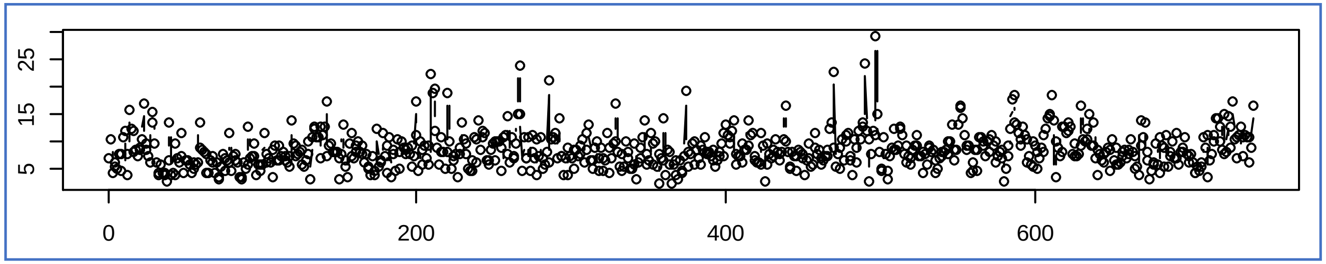
Lake Michigan 2015 sampling

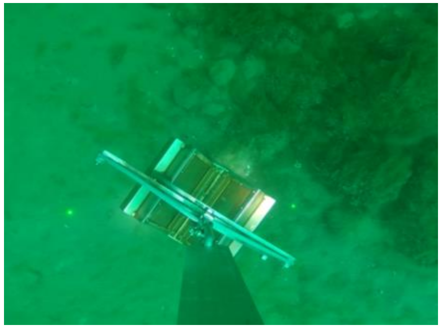
From each stations:

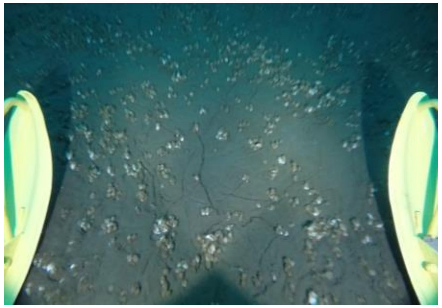
1. Three Ponars were processed for *Dreissena* density, biomass and size
2. *Dreissena* coverage was calculated using GoPro camera mounted on a Ponar grab
3. At 43 stations coverage was calculated from **100 frames** randomly distributed along 500 m benthic sled transects



4. At 5 transects *Dreissena* coverage was calculated from the entire transect (**600 – 800 frames**, “true average”)

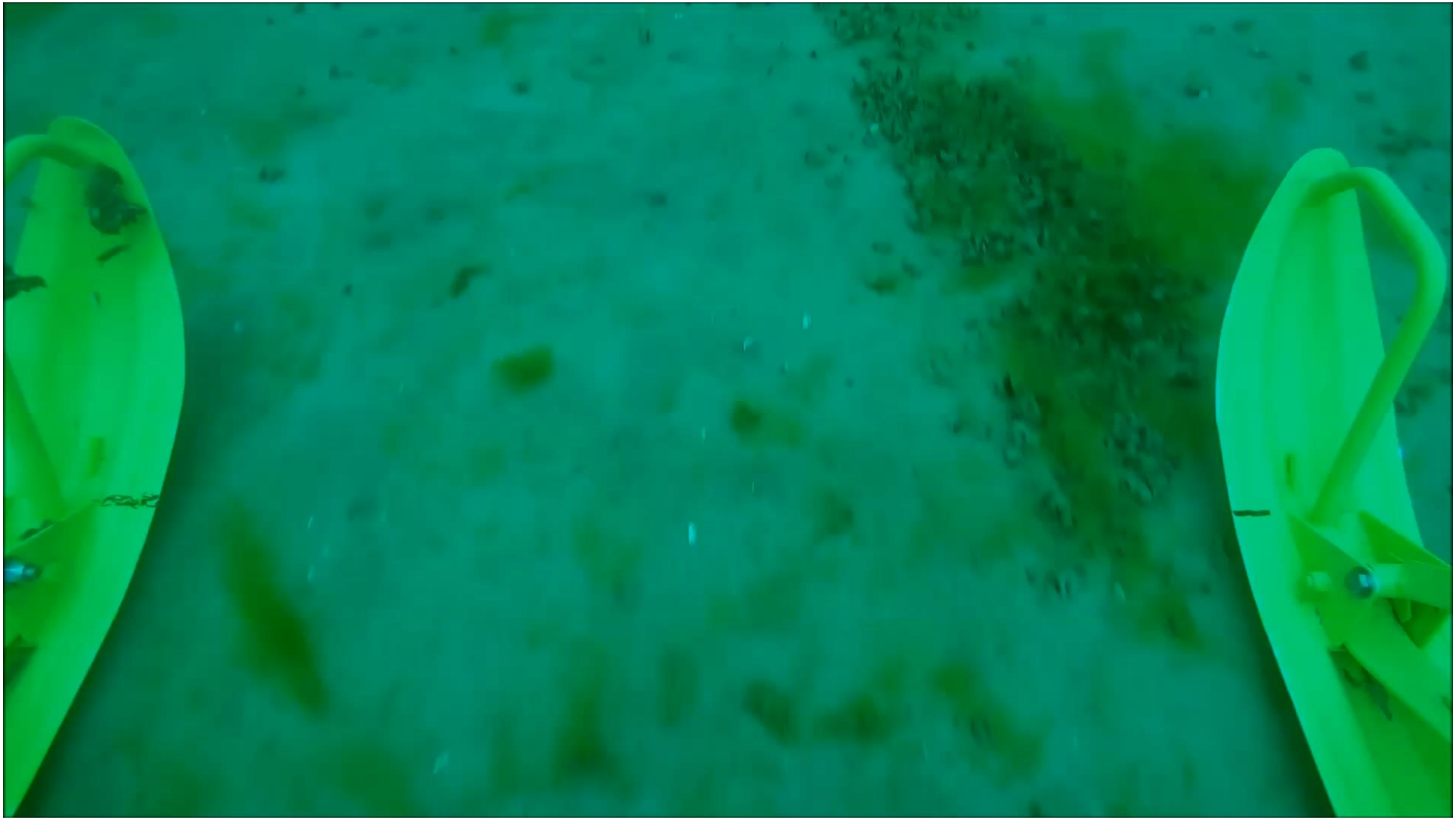






Video clip (160 m depth no *Dreissena*)

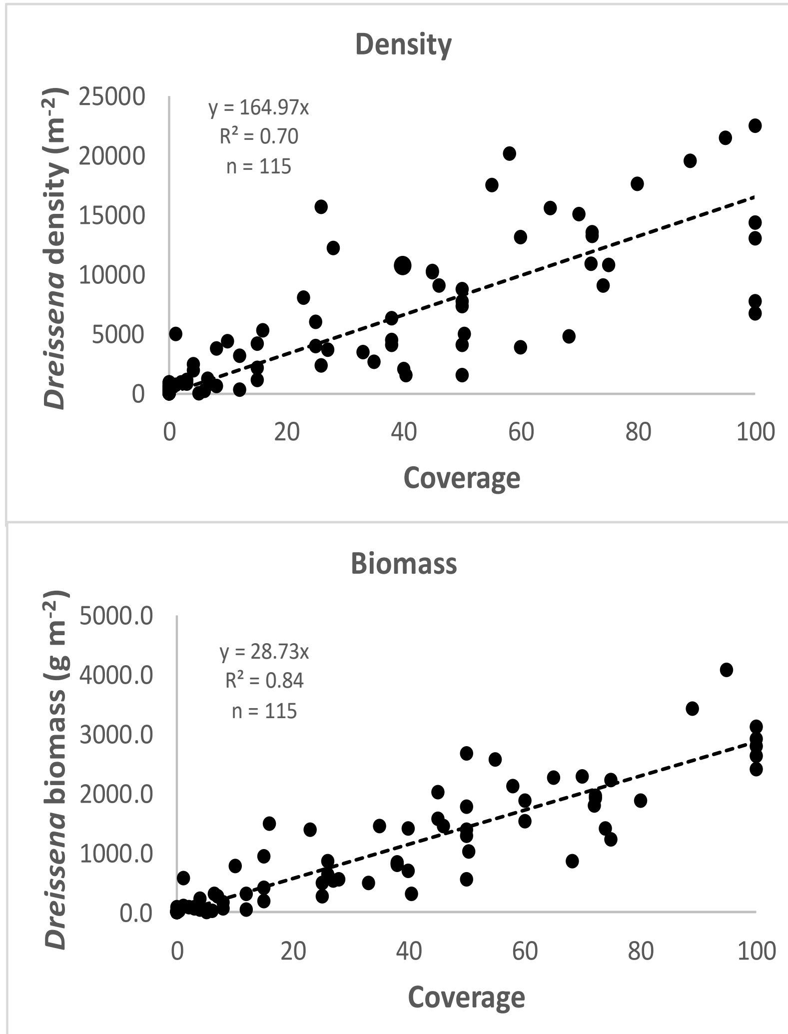
< 30 m, Highly Heterogenic Aggregations (22 m)



30 – 100 m, Almost Complete Coverage (80 m)

> 100 m, Small Druses Evenly Distributed (120 m)

Converting coverage into density and biomass



Correlation between *Dreissena* bottom coverage in Ponar grabs and density and biomass obtained from same grabs in Lake Michigan in 2015

2015 Lake Michigan Video Transect vs. Ponar

Traditional sampling (143 stations, 469 Ponars, total sampling area = **22.5 m^2**):

- Sorting of 469 samples – ca. 470 days,
- counting and measuring – ca. 130 days **total 2.4 years of technician time**
- + time for data analysis.

Video transects (43 tows,100 images/transect analyzed) = **645 m^2 of bottom area**

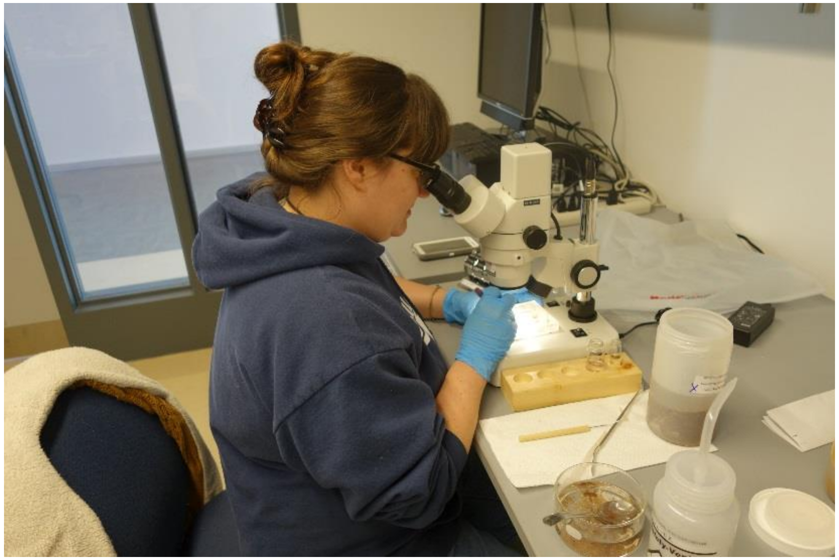
- **2 month of technician time**

Video transects (43 tows, entire transects analyzed) = **3,225 m^2 of bottom area**

- **4 month of technician time**

Suggested total sampled area is equal to **67,187 Ponars,** which will require **> 200** years of technician time to process and **> 60,000** L of formalin on board R/V Lake Guardian

Video transects vs. Ponar grabs

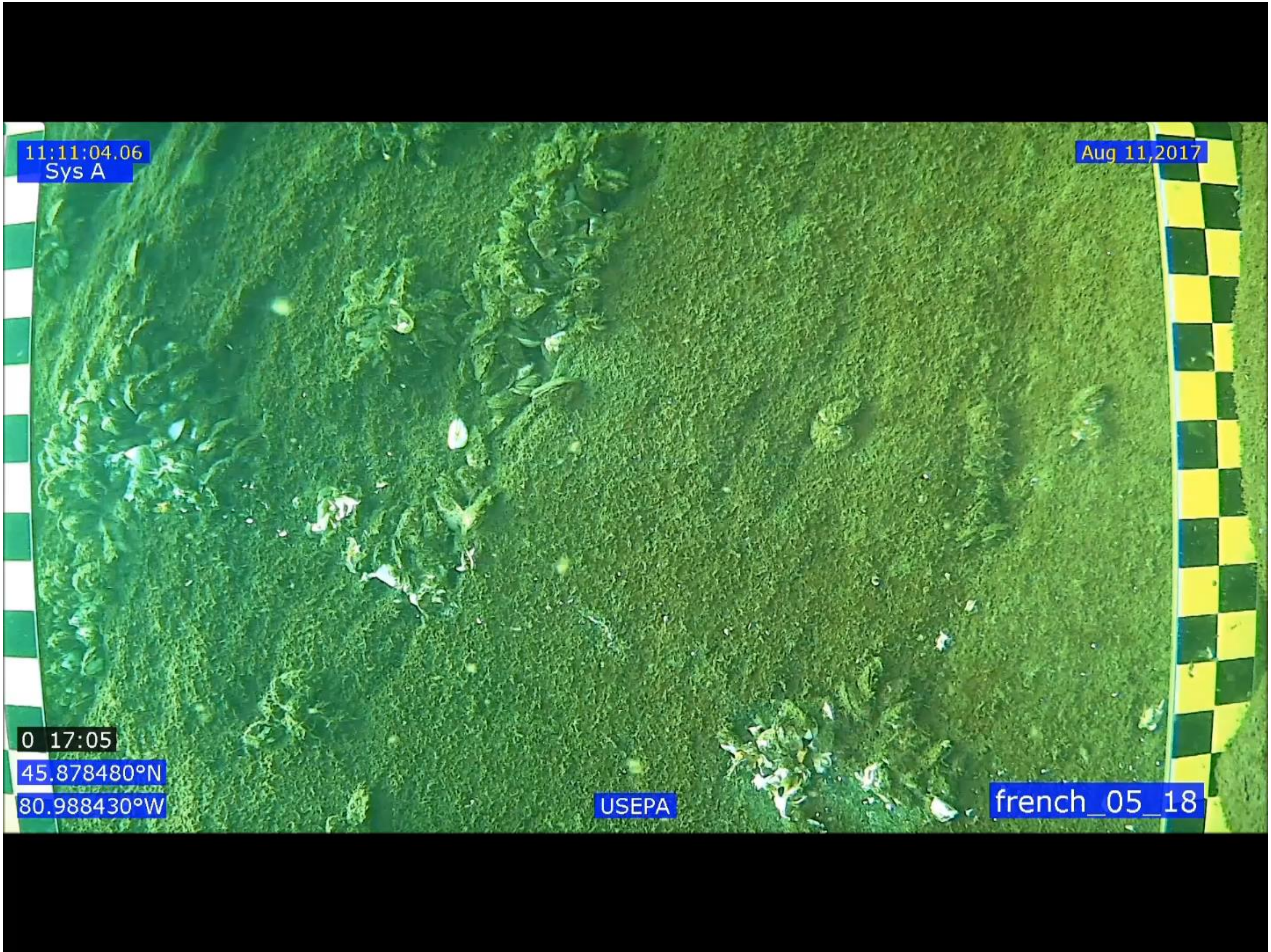


4 months of watching movies and eating popcorn

or

200 years of sorting dead *Dreissena* and smelling formalin?

Georgian Bay (12 m)



Acknowledgments

Questions?