

Zebra Mussels in Lake George

Eradication, Management & Current Status

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Invasive Mussel Collaborative (IMC) Webinar

September 6, 2018

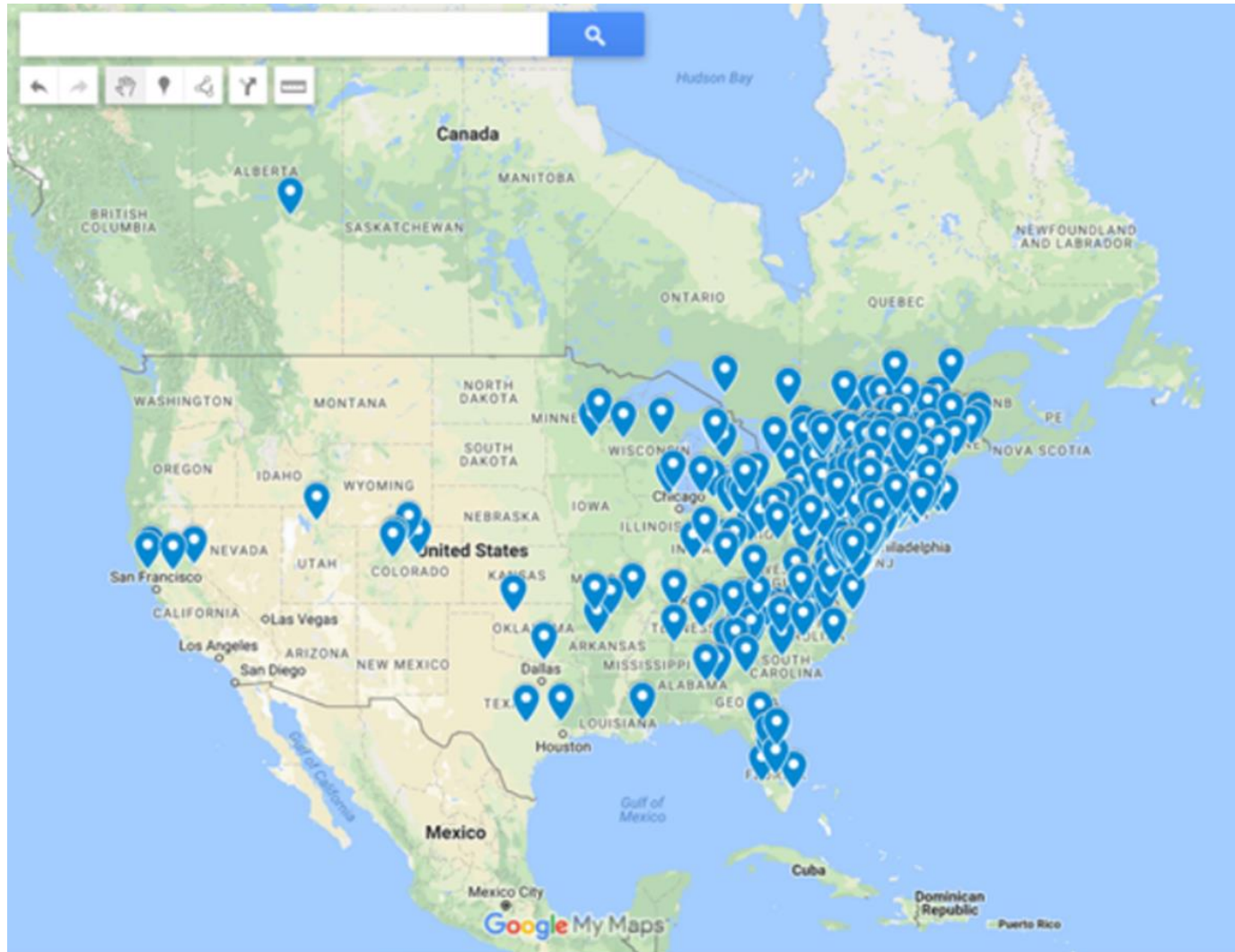
Aquatic Invasive Species and Lake George

Currently five known invasive species in Lake George



Well over \$10 million spent on AIS management to date

Origin of Boats & Invasive Species “Captures” Entering Lake George (2008 – 2011)



- Boats arrived from 678 unique lakes, ponds & rivers from the US and Canada
- ~ 25,000 inspections annually
- 1-2% of boats with visible AIS



Zebra Mussels in Lake George

- Zebra mussels have been or are being introduced into Lake George (at least since 1995).
- Introductions are probably due to transport by boats and water from infested water bodies.
- Based on the water chemistry and nutrient status of the lake, Lake George is at a borderline risk level for supporting zebra mussels.

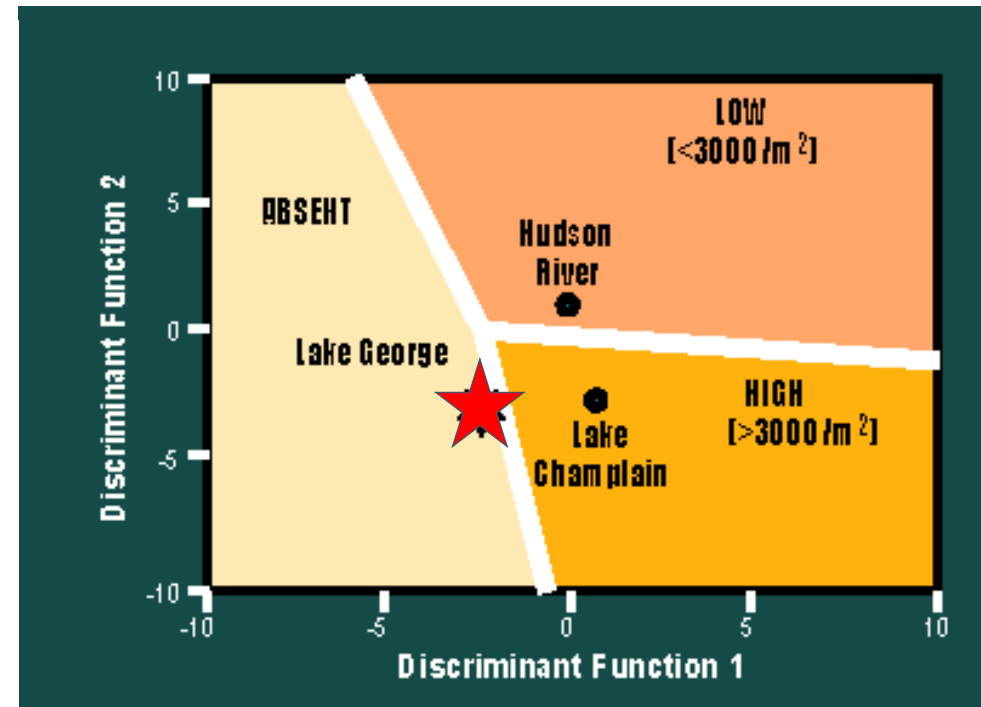


Initial Model Assessment – Based on Calcium Requirements – LOW RISK

Table 1. Ecoregional risk classifications based on calcium concentration sample statistics in US streams and rivers (USEPA EMAP unpublished; USEPA WSA 2006)

<i>Risk class</i>	<i>Distribution of calcium concentrations at sites</i>
Very low	75th percentile $< 12 \text{ mg L}^{-1}$
Low	$12 \text{ mg L}^{-1} \leq 75\text{th percentile} < 20 \text{ mg L}^{-1}$ or 75th percentile $< 21 \text{ mg L}^{-1}$ and maximum $< 28 \text{ mg L}^{-1}$
High	mean $\geq 28 \text{ mg L}^{-1}$ and 25th percentile $> 12 \text{ mg L}^{-1}$
Highly variable	$\geq 15\%$ of sites with $\text{Ca} < 12 \text{ mg L}^{-1}$ AND $\geq 15\%$ of sites with $\text{Ca} \geq 28 \text{ mg L}^{-1}$

Whittier et al (2008)



Ramcharan et al (1992)

Adult Zebra Mussels Detected in Lake George, NY
Dec 18, 1999 By Volunteer Divers Cleaning-up Trash



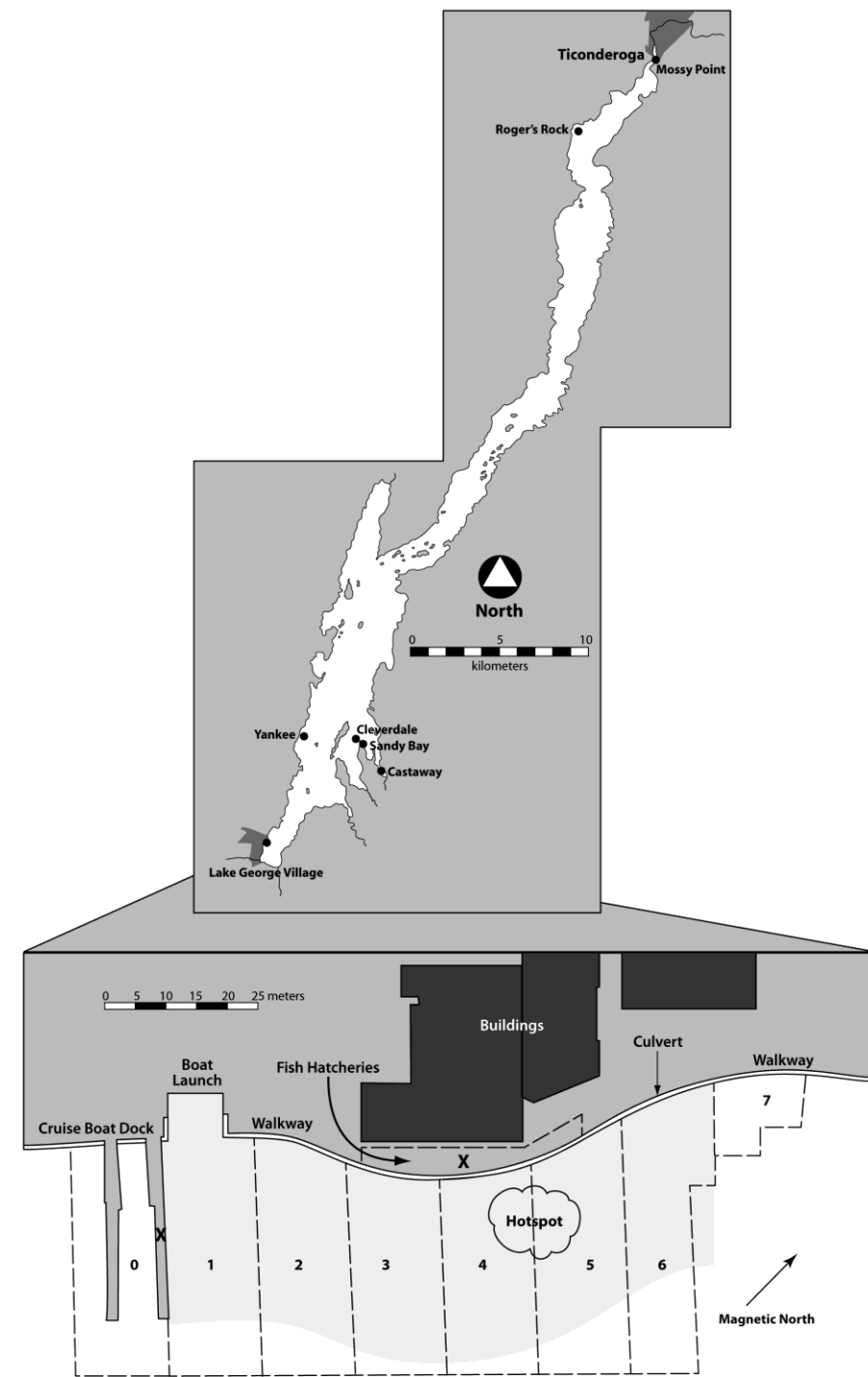
Lake George Village Site Delineation

- SCUBA Surveys-Delineation of “infected” area
 - 3900m²

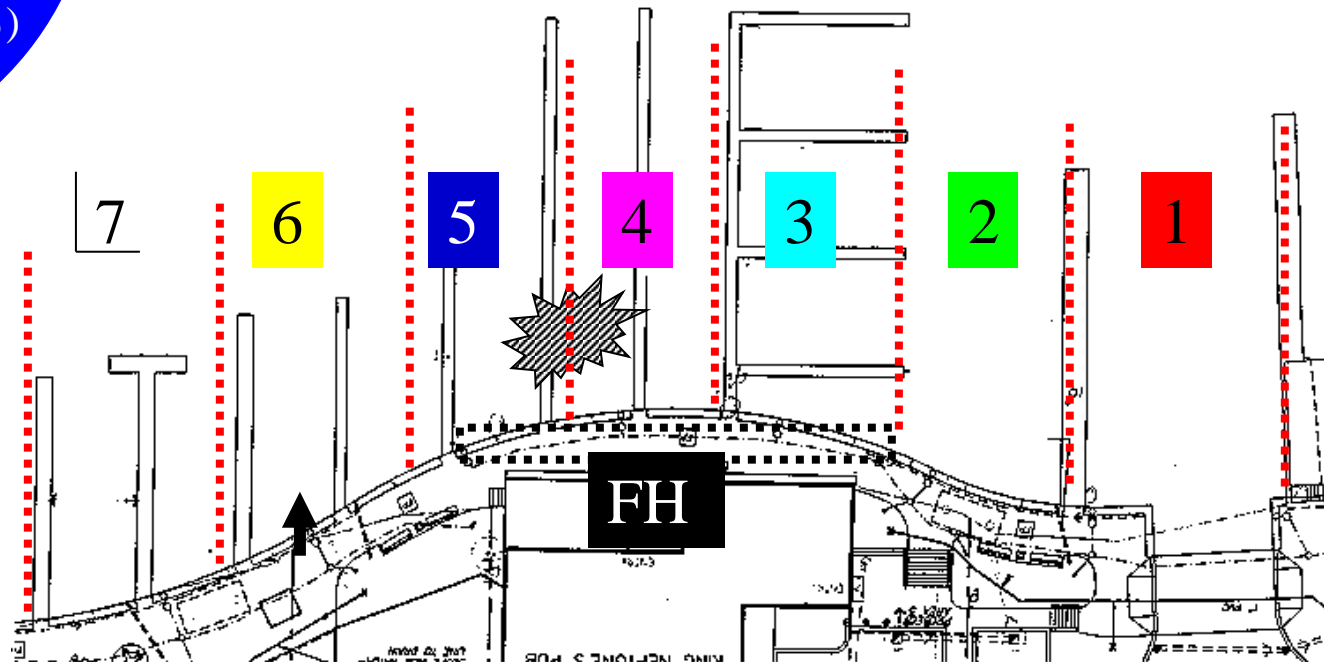
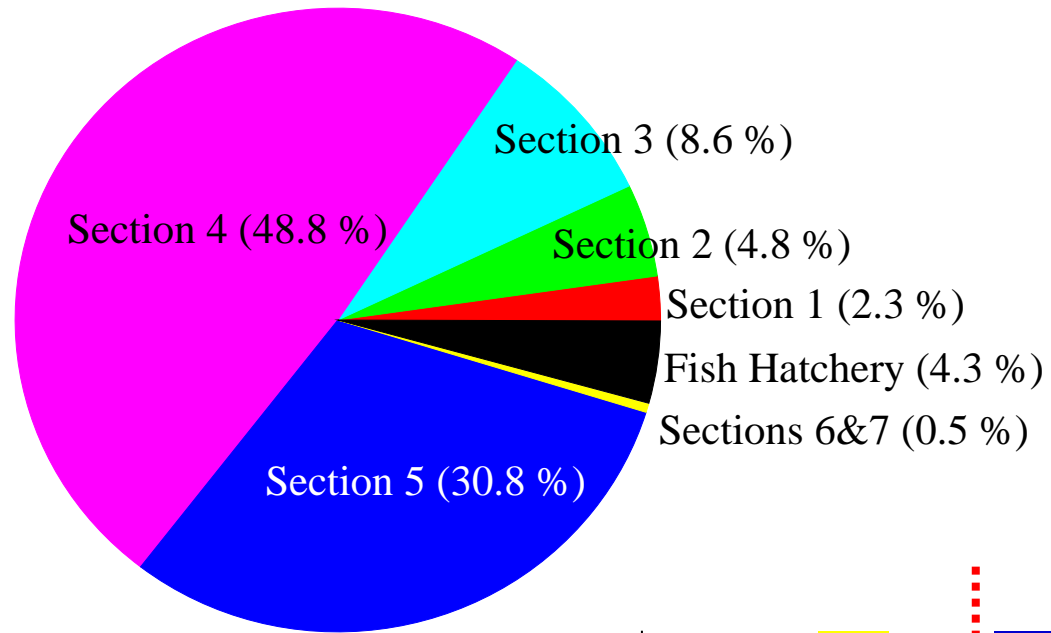


Lake George Village Site

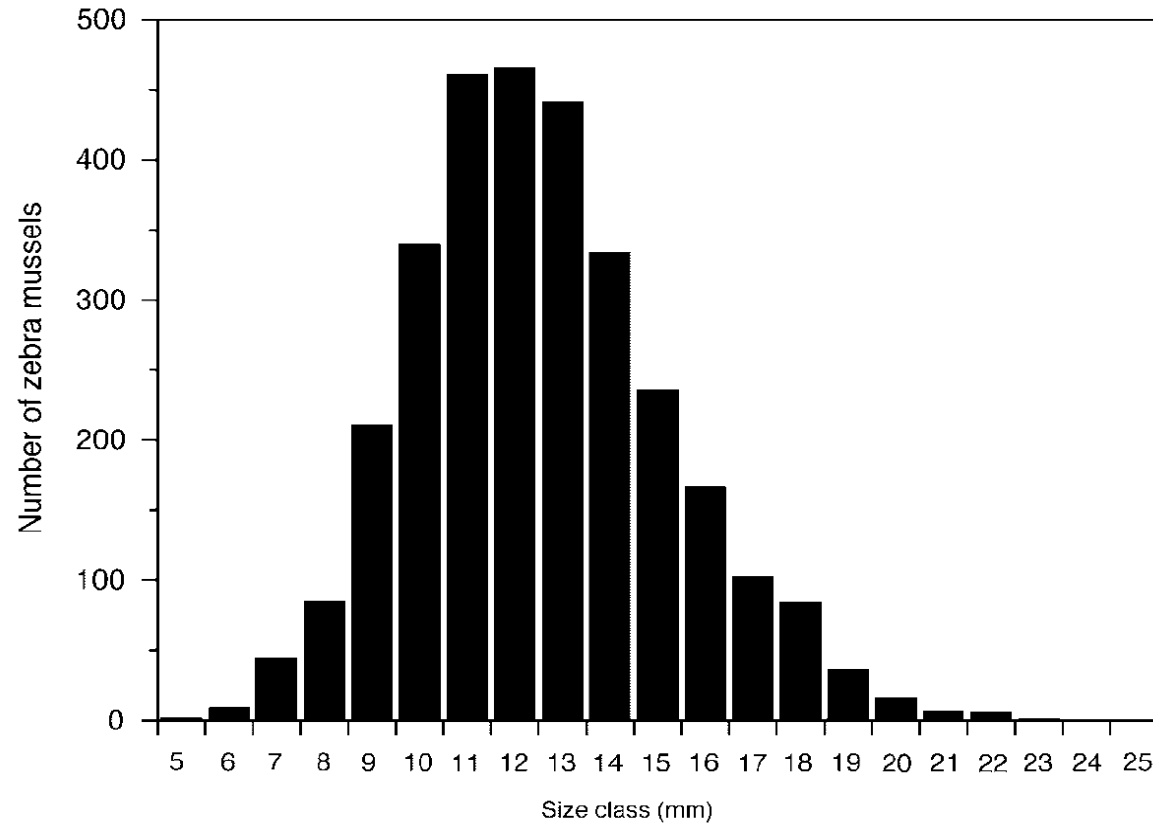
- **Site Divided into Sections-**
 - Facilitate Systematic Survey
 - Guide Removal Efforts
 - Gain Scientific Information
- **Section Specifics-**
 - Approx. 50ft wide (12 lanes 4ft each)
 - Delineated with rebar and nylon line
- **Section Characteristics-**
 - Large Permanent Docks
 - Fish Hatcheries
 - Culvert
 - Hotspot



Initial Survey (April 2000)



Initial Survey (April 2000) – Population Size Structure



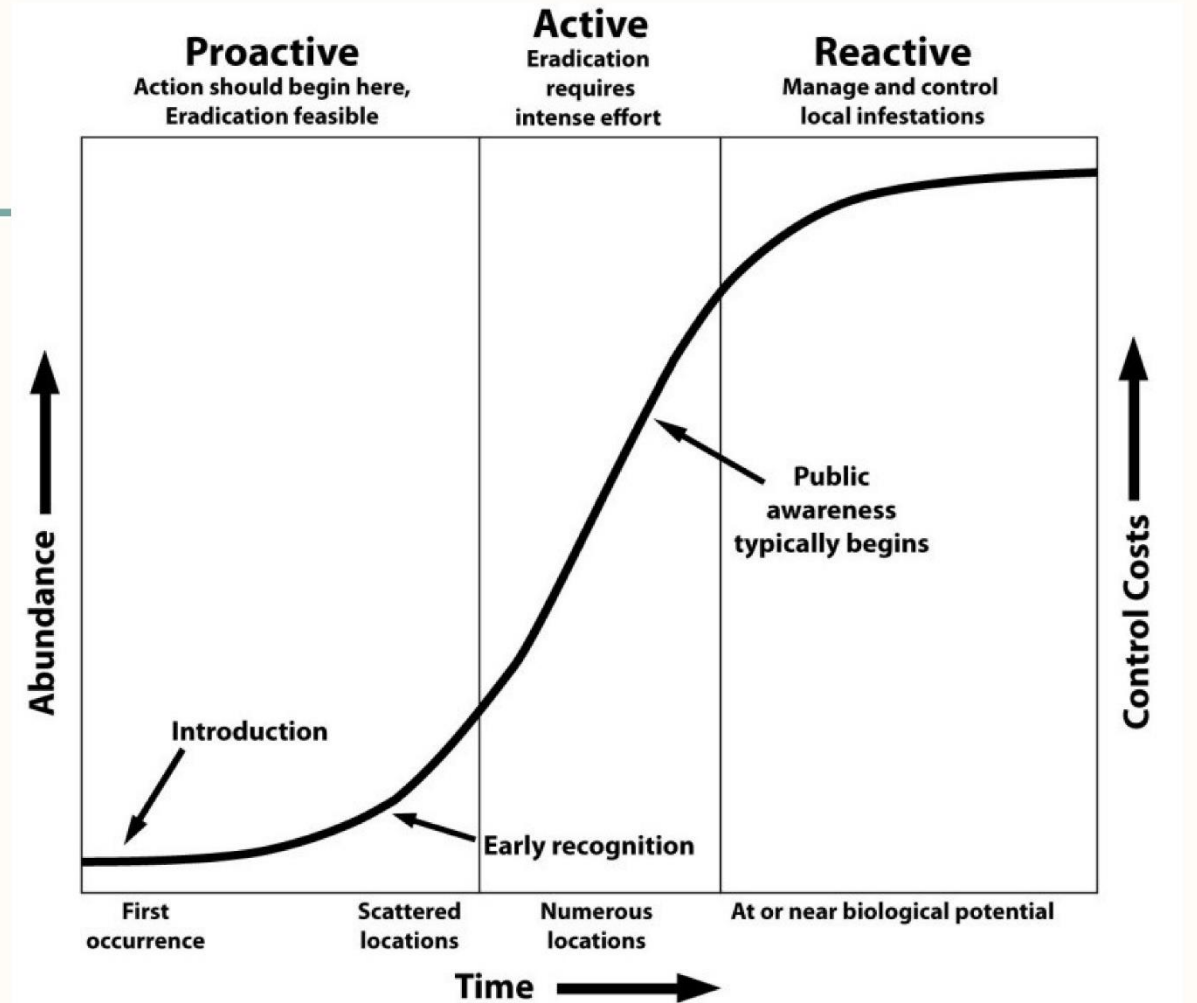
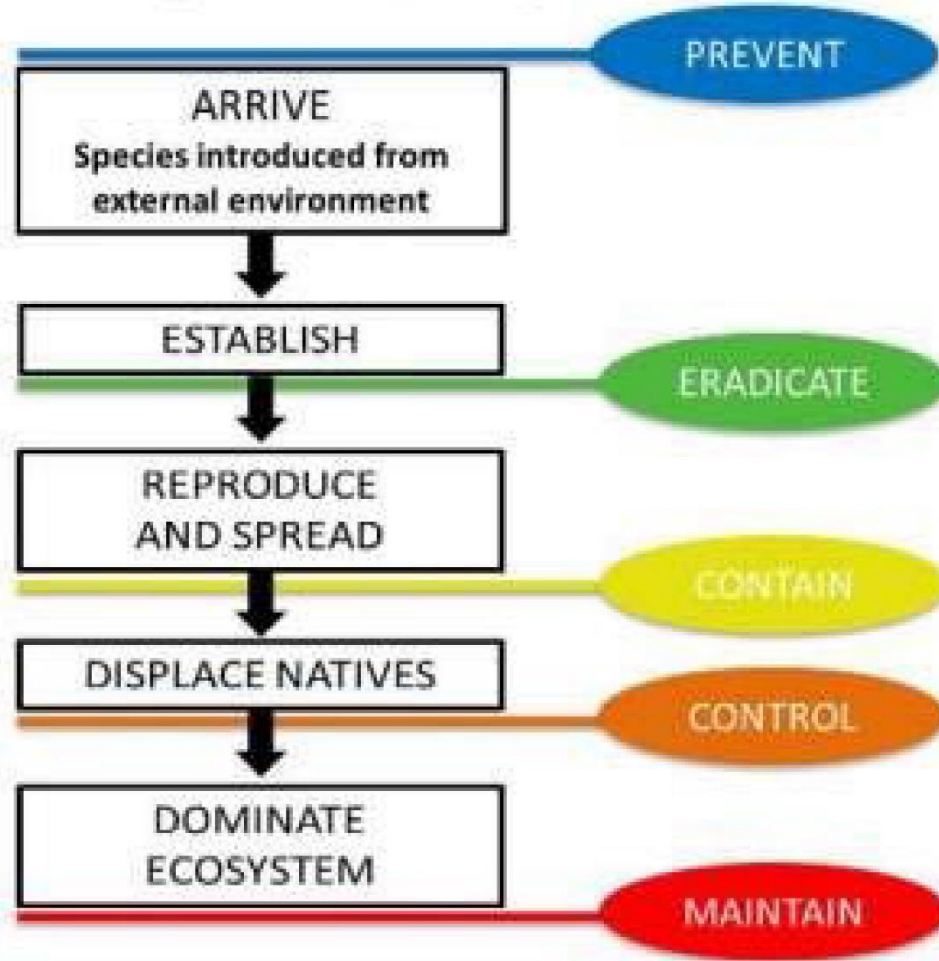
Single Cohort?

Based on size & estimated growth rates, probably introduced in 1997 or 1998 followed by 1 successful recruitment

OPTIONS?

Invasion Curve

Stages of Biological Invasion



Phases of Invasive Species Invasion and Control

Options Considered

1. Do Nothing
2. Construct Cofferdam-Costs and Permits
3. Chemical Treatment-Permits Unlikely
4. Benthic Mats – Efficacy?
5. Heat Treatment – Efficacy? Concerns about diver safety
6. SCUBA Hand-Harvesting-1 Permit, Rapid Action



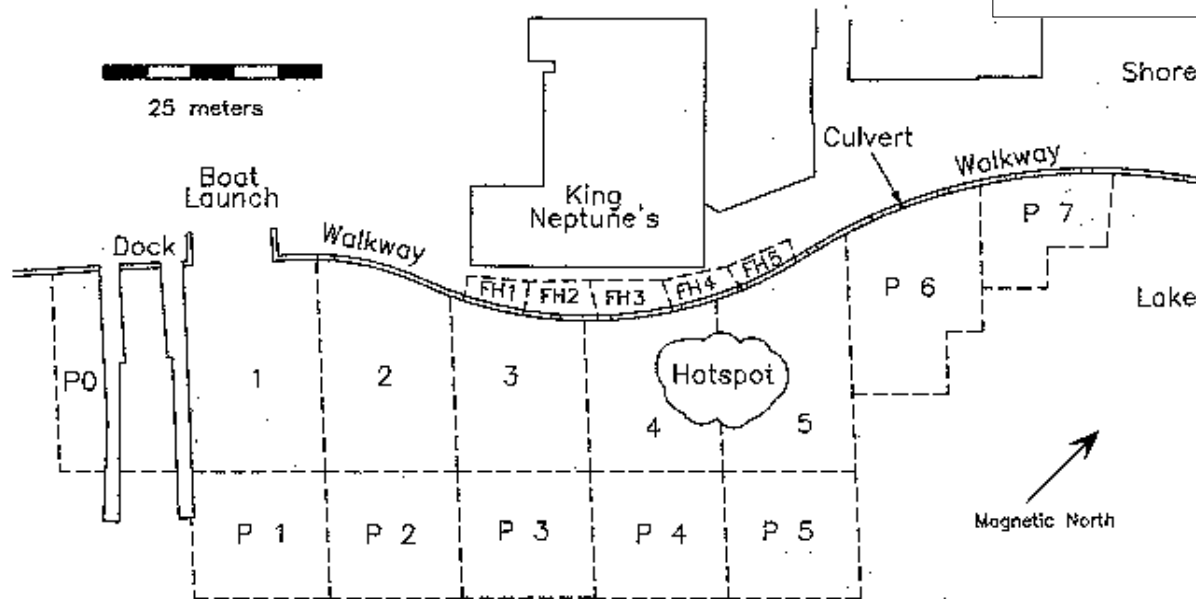
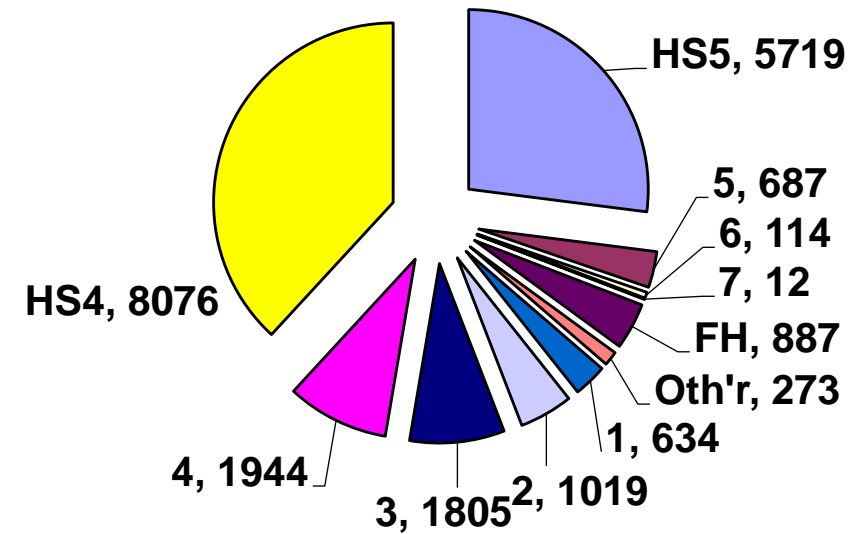
Course of Action

- Assess the Problem
 - Determine the Population Size and Area of Infestation
- Eradicate The Zebra Mussel Population if Possible
 - Hand Harvesting by SCUBA
- Determine Why the Infestation Occurred
 - Water Chemistry, Evidence of Introductions, etc...
- Determine Whether Zebra Mussels Were Growing and Reproducing
 - Observations of Population Structure and Laboratory Studies



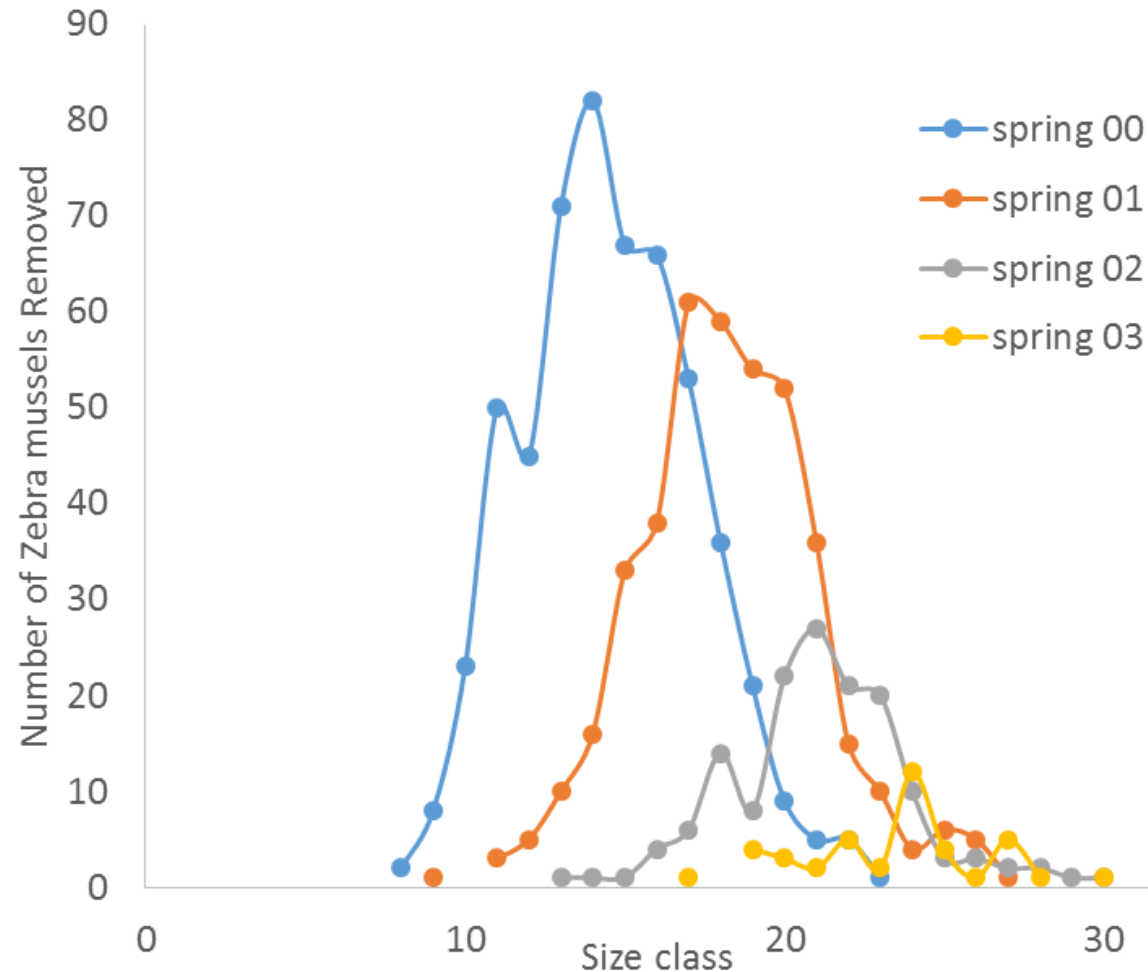
Lake George Village Zebra Mussel Removal

December 1999
– May 2007

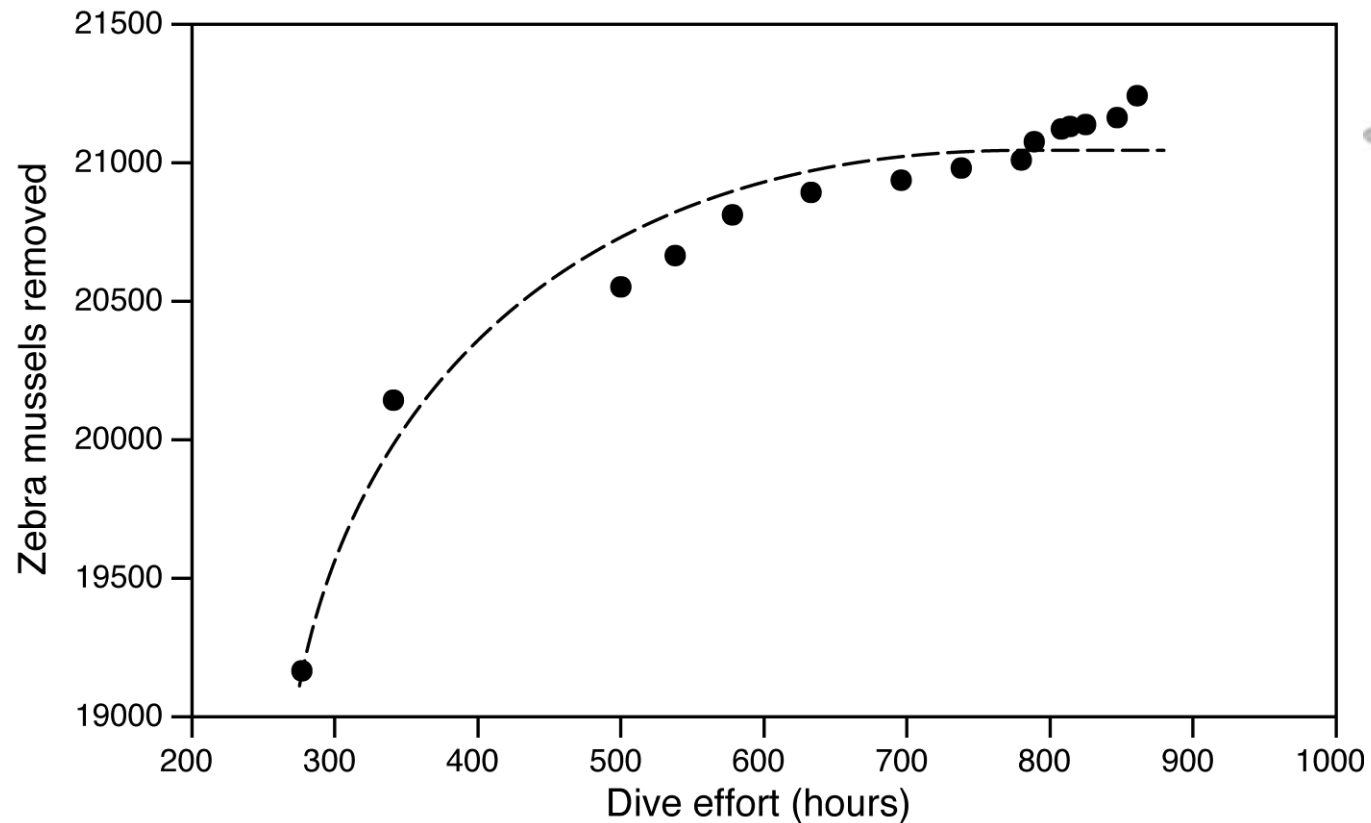


Adult Removal- Localized Eradication

- **Lake George Village (Neptune's)**
- Greater than 21,000 animals removed from the Lake
- Early detection led to localized eradication

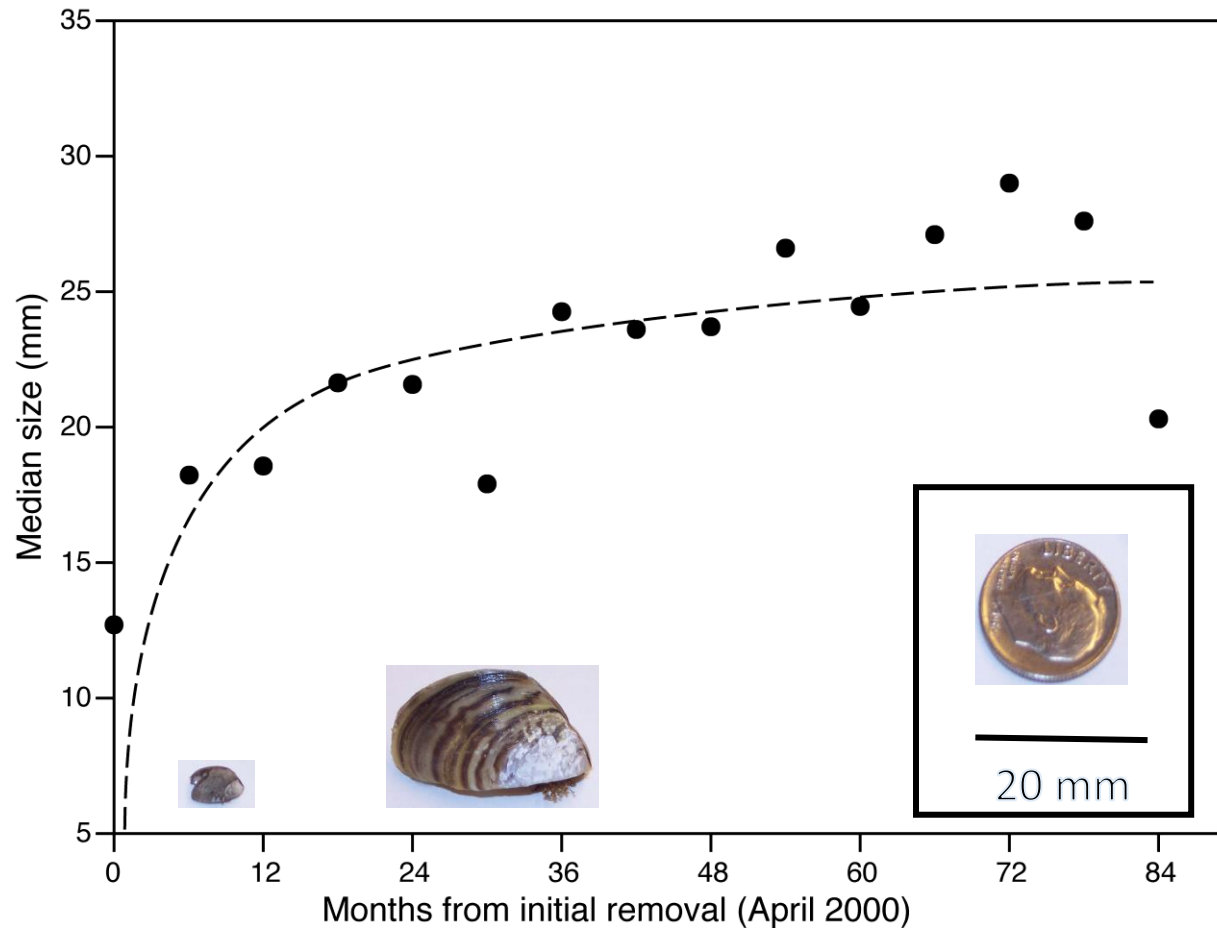


Removal Rate



Zebra mussels removed from the Lake George Village site as a function of dive effort from the initiation of the removal effort in April 2000. The removal rate was defined by a single parameter exponential growth function ($r^2 = 0.942$).

Growth Rates



Growth of zebra mussels estimated from shell length of animals removed from the Lake George Village site from April 2000 to September 2007.
Growth was predicted by a single parameter hyperbola function.

COSTS & FINANCING \$\$\$\$

COSTS:

- Diving (860 in water hours)
- Shore Support and Dive Prep (est. 3440 hrs)
- Water Sample Collection & Data Logging & Analyses (est. 1720 hrs)
- Reporting
- One full-time scientist & small amount for other professionals

FINANCING:

- New York Sea Grant
- Helen V. Froehlich Foundation
- Lake George Watershed Conference
- FUND for Lake George

**Very generous in-kind
services & volunteers**

Follow-up & Continuing Studies ... What Happened?

The Good News

- **No Evidence of Further Spawning or Recruitment at the Neptune's Pub Site**
- **No Veligers**
- **No Recruits on Spat Traps**
- **No New Juveniles or Adults**

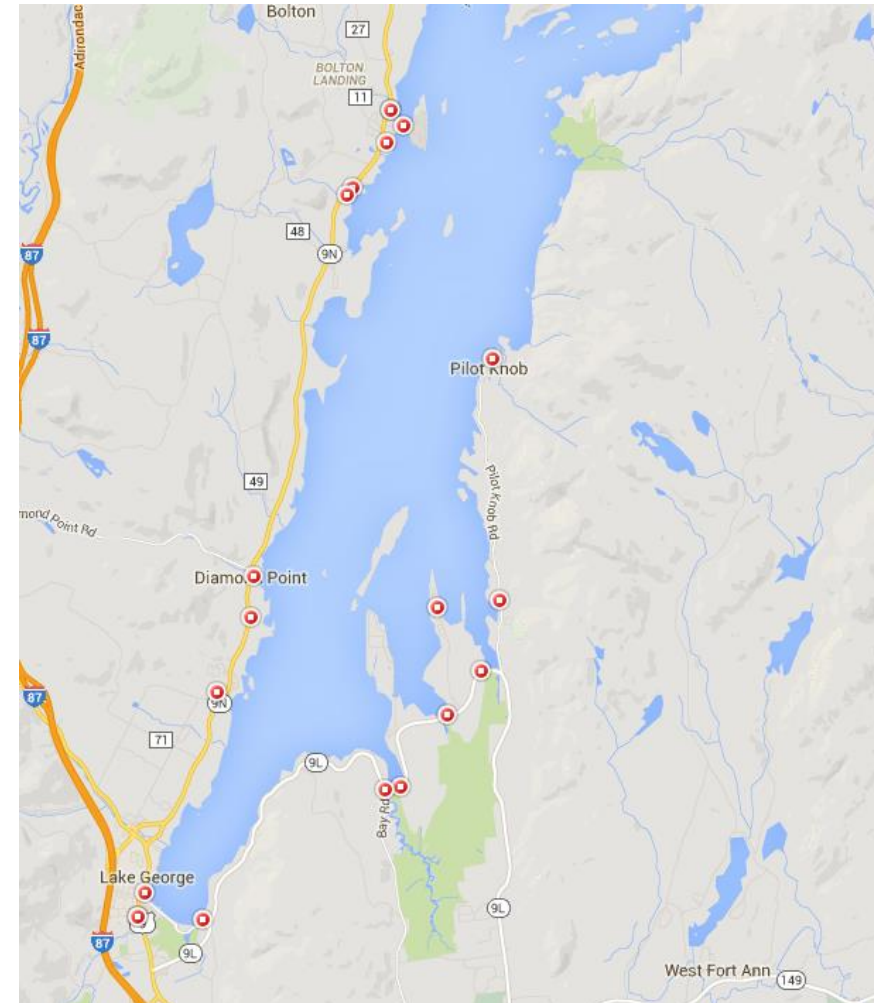
Eradication of Zebra Mussels from Lake George???



Continued Vigilance

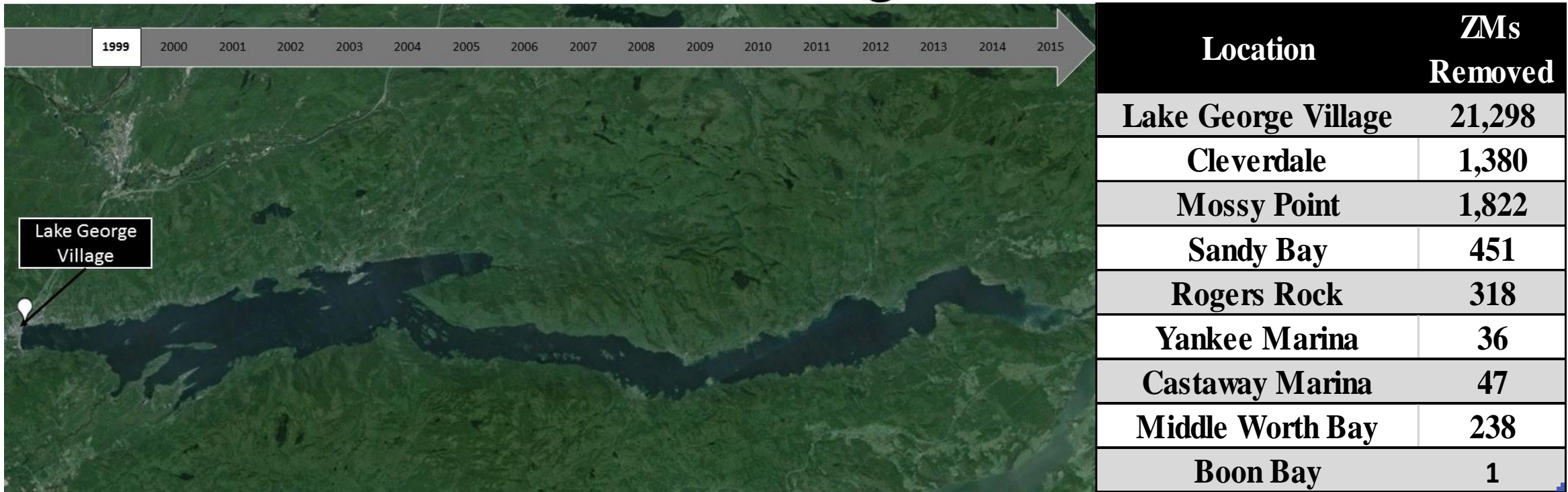
Additional Surveys – Marinas (High Risk Sites)

- Yearly marina survey
- Several transects along docks, sea walls, boat launches etc.
- Calcium concentrations measured
- All mussels found removed, measured and preserved



Continued Removals

Zebra Mussels In Lake George



Respond to Citizen Reports

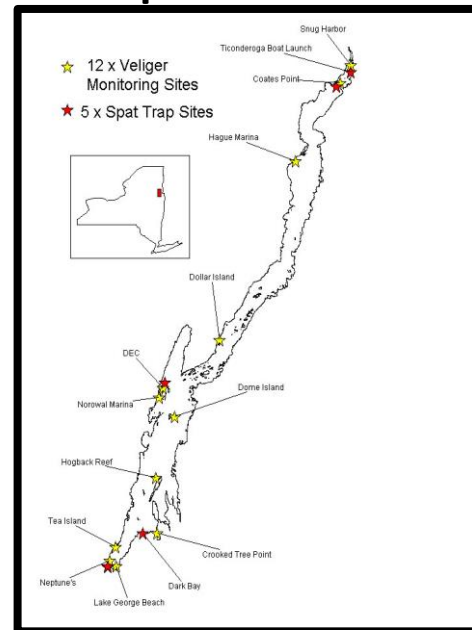


- ~2x per summer a concerned citizen contacts DFWI about an “invasive species”
- Within 1 week a survey is conducted
- Results determine next steps



Veliger Monitoring

- 1995 to present
- 12 locations visited bi-weekly through the summer months
- 200 liters of water concentrated
- Examined with cross-polarized microscopy



Recruit Monitoring

- 1995 to 2013
- 4 locations visited twice a year
- 1 detection event (Mossy Pt)

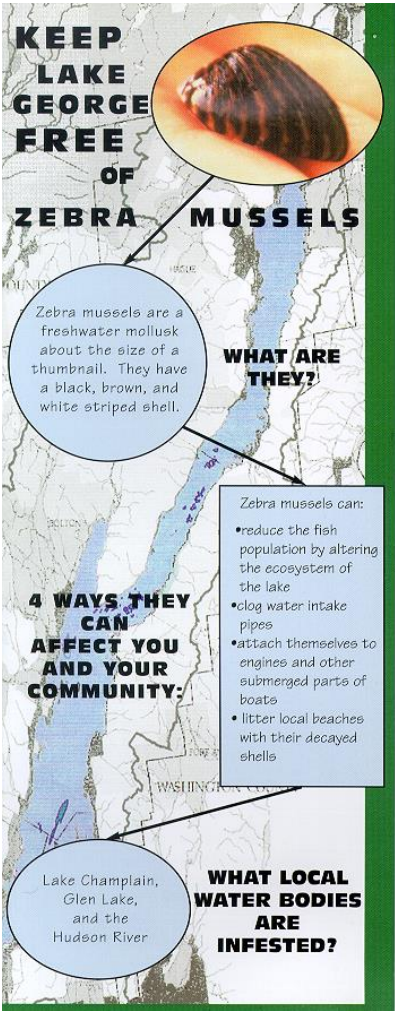
Program discontinued,
cost did not justify return



Prevention – Education & Outreach

Raising Public Awareness & Knowledge

Public (Free) Boat Washes



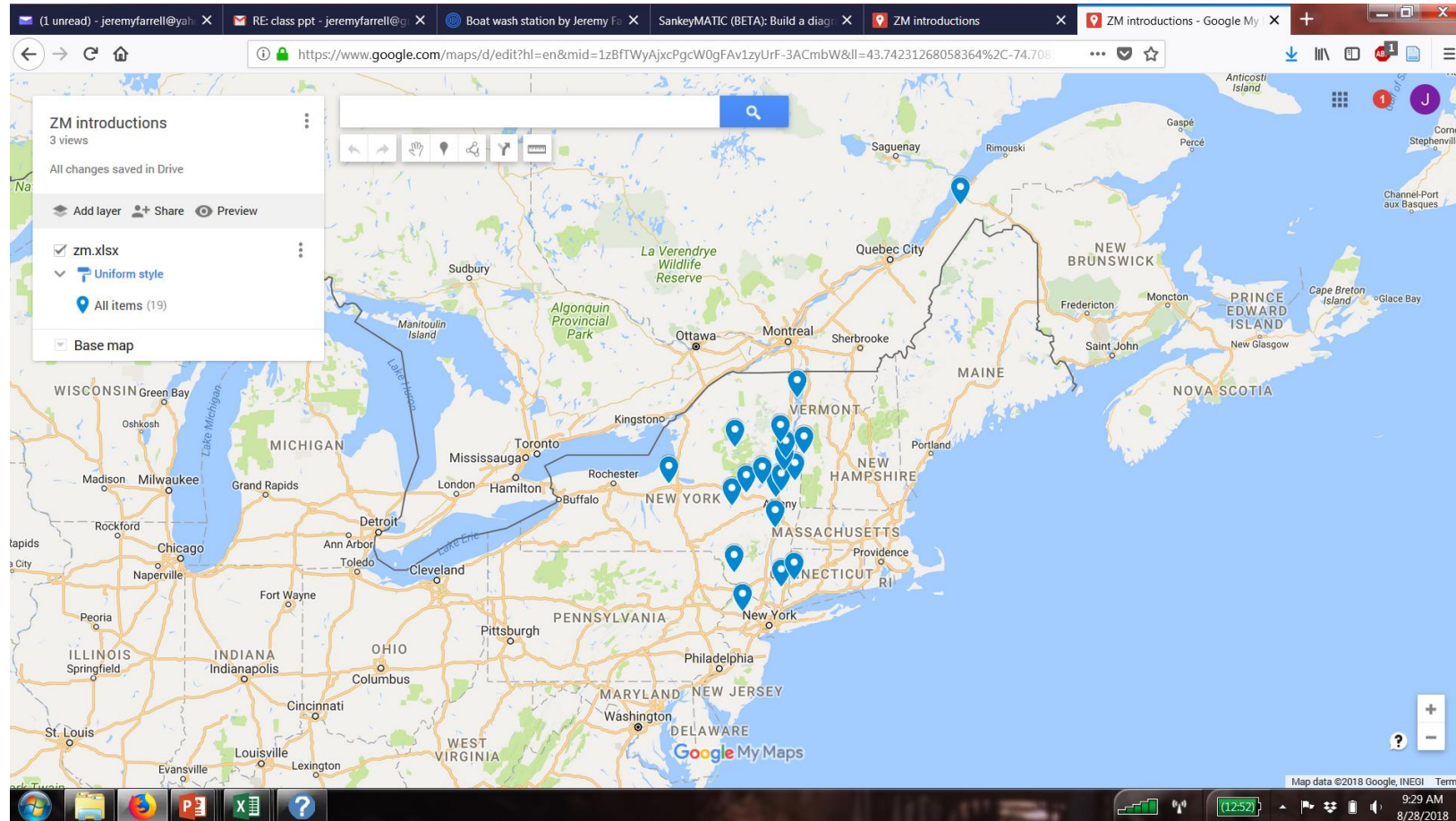
STOP AQUATIC HITCHHIKERS!

Prevent the transport of nuisance s
Clean all recreational equipme
www.ProtectYourWaters.net



Boat Inspection Program – Results (2014 – 17)

Site of origin of boats detected entering Lake George with Zebra Mussels



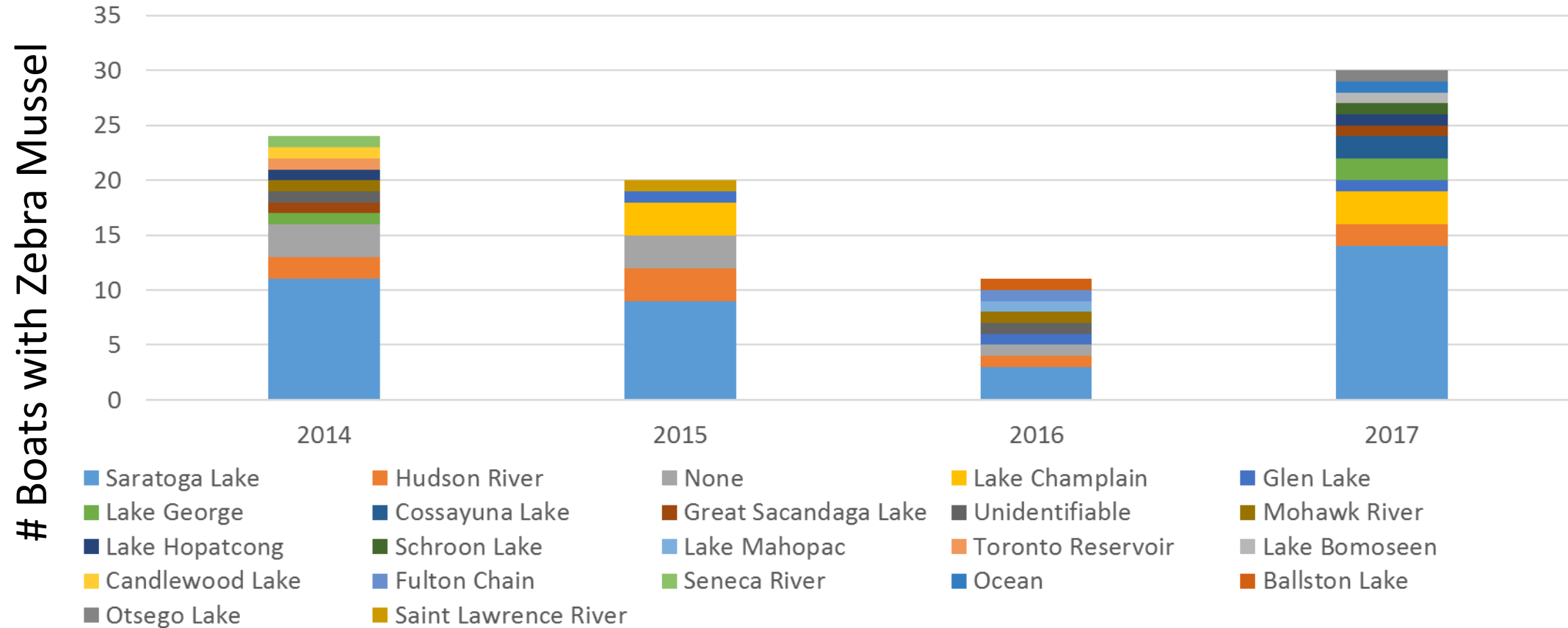
~ 25,000 Inspections
Annually



<https://www.google.com/maps/d/edit?hl=en&mid=1zBfTWyAjxcPgcW0gFAv1zyUrF-3ACmbW&ll=43.74231268058364%2C-74.7083137871582&z=6>

Capture Interventions

Origin of Vessels Transporting Zebra Mussels to Lake George

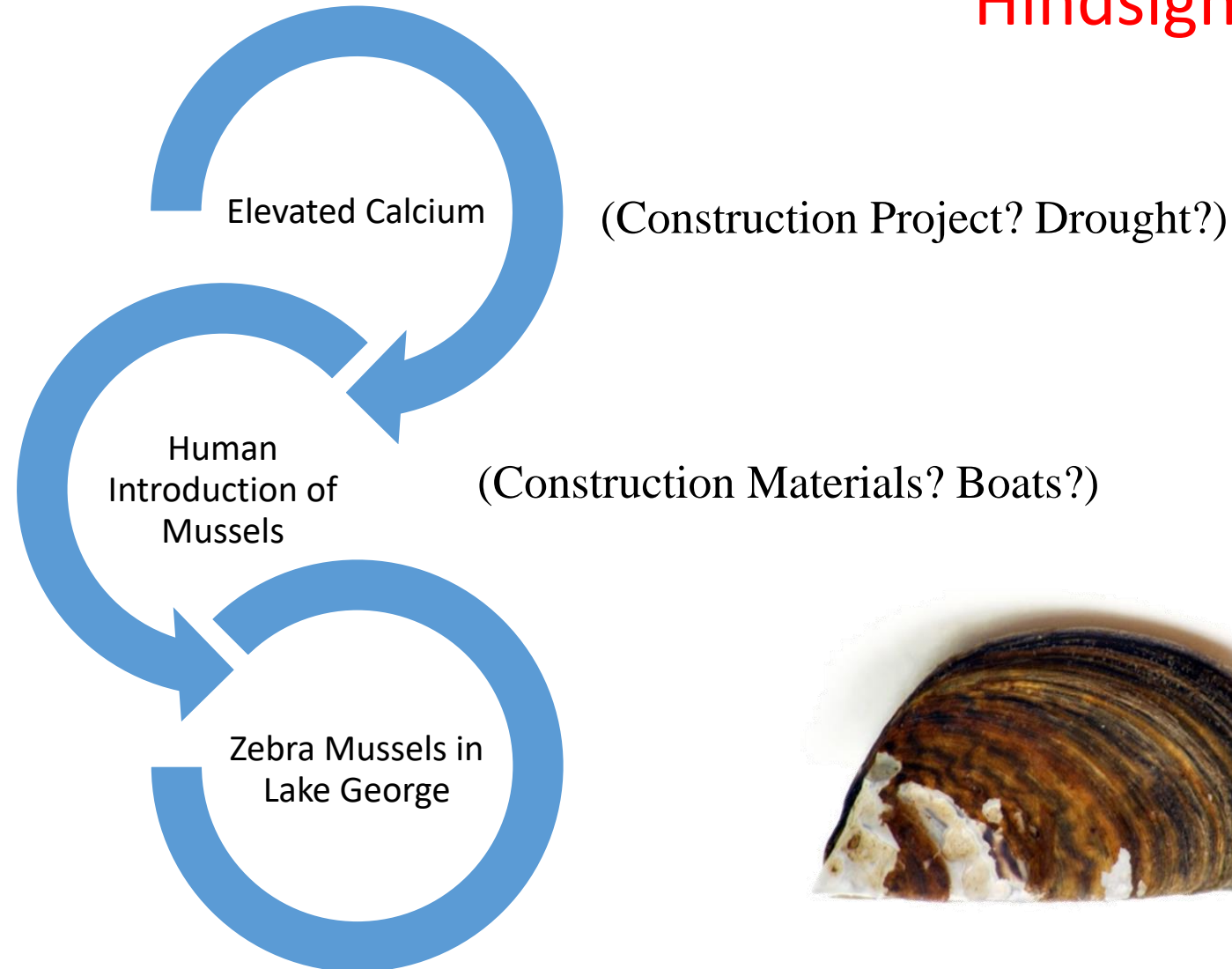


Prevention!

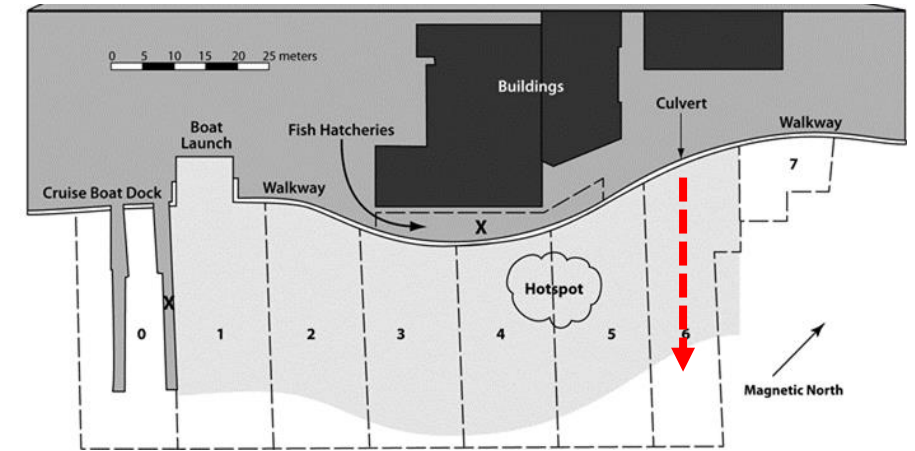
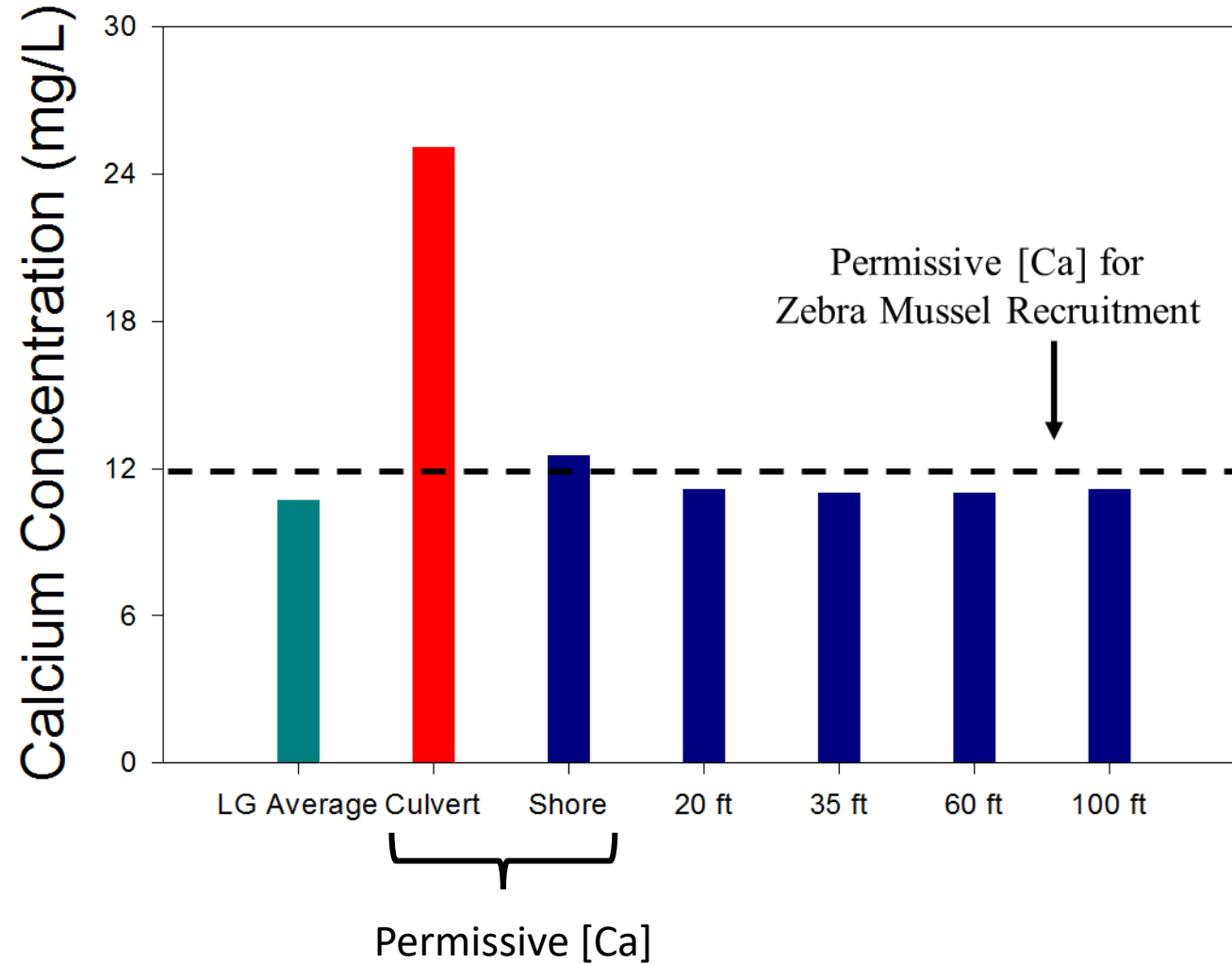
10 – 30 potential introductions per year

So... What We Think Happened

Hindsight is 20/20 (maybe)

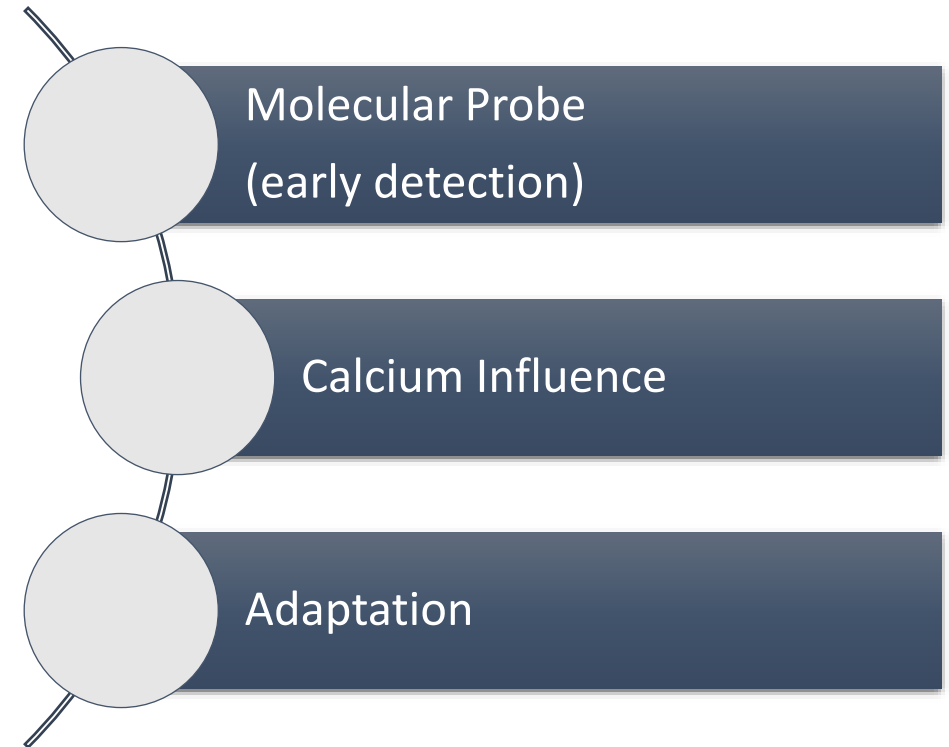


Neptune Pub Site Calcium Levels (December, 1999)



Additional Insights – Post Hoc Studies

- For Zebra Mussels
- Continuing studies
- Adult & larval growth and survival
- Habitat preference in low ca environment – interactions with Asian clams and unionid mussels
- Increasing salt & other deicing agents
- Other invasive species introductions
- Etc...



Origin of Early Monitoring Program in Lake George - Molecular Probe

- Zebra mussel specific probe developed and validated
- Quagga mussel specific probe could be developed
- Implications for eDNA and boat wash stations
- Useful early detection tool

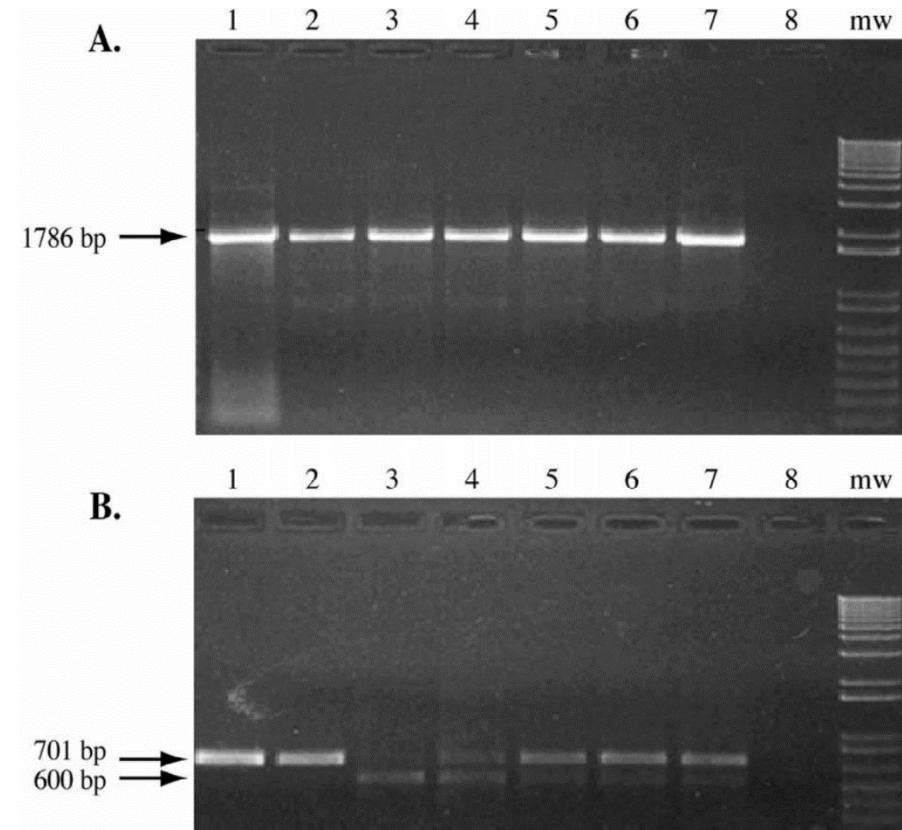


Figure 4. PCR Detection of spiked zebra mussel larvae in plankton sample. (A) PCR amplification of a 1786 bp fragment of the 18S rRNA gene produced using the eukaryotic universal primers UnivF-15 and UnivR-1765 and (B) amplification of the 701 bp zebra mussel-specific amplicon produced using the zebra mussel specific primer set UnivF-15 and Zeb-715a. In both panels (A & B) lane 1, purified zebra mussel DNA (positive control). Lane 2, DNA extracted from a Lake Champlain, VT plankton sample. Lane 3, DNA extracted from a Lake George plankton sample. Lane 4, DNA extracted from a Lake George plankton sample spiked with 1 zebra mussel veliger. Lane 5, DNA extracted from a Lake George plankton sample spiked with 5 zebra mussel veligers. Lane 6, DNA extracted from a Lake George plankton sample spiked with 10 zebra mussel veligers. Lane 7, DNA extracted from a Lake George plankton sample spiked with 25 zebra mussel veligers. Lane 8, negative control (no DNA template). mw, molecular weight marker (1 kb ladder, Gibco BRL, Grand Island, NY).

Bioassays to Validate Model Predictions

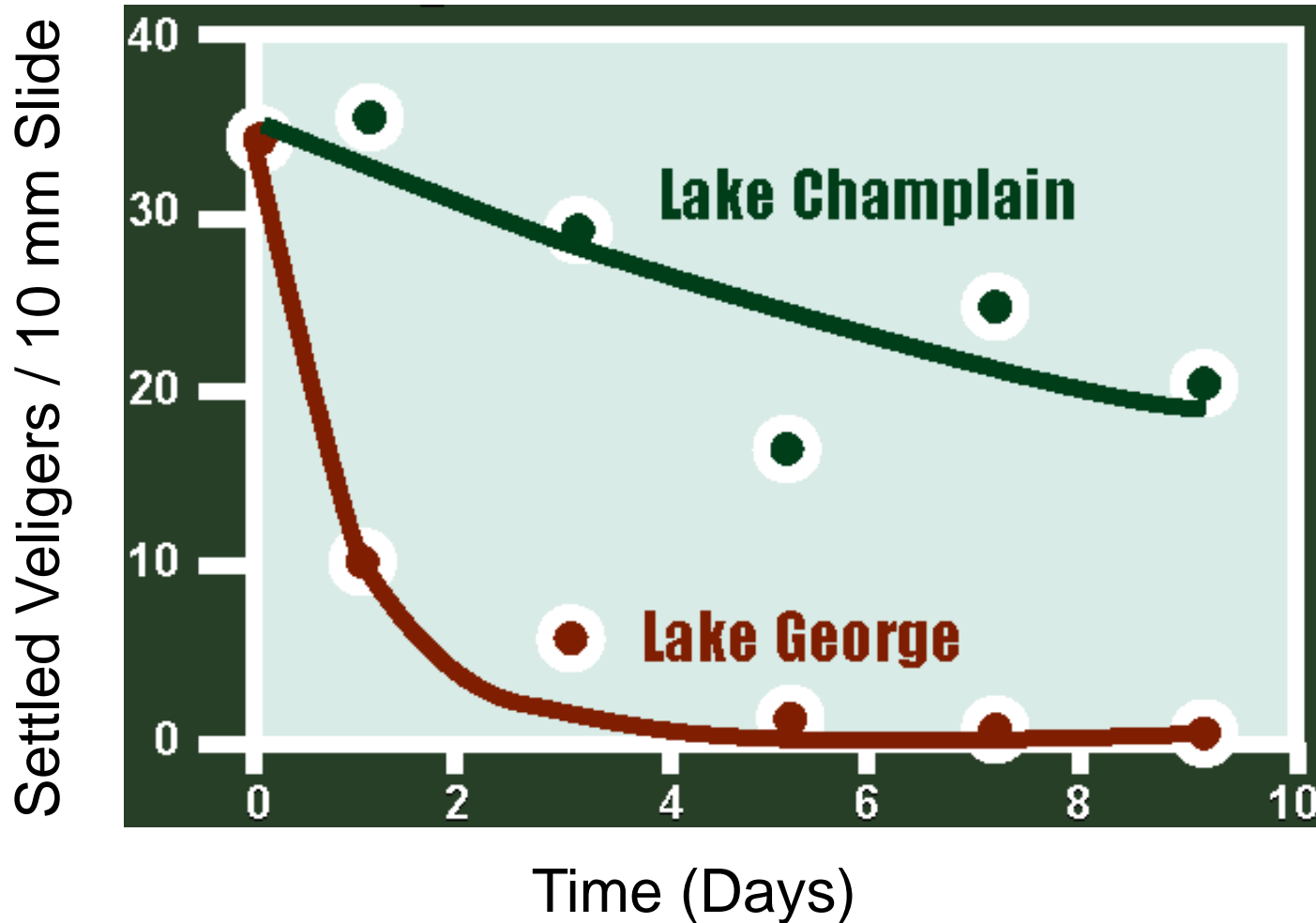
Adult Survival in Lake George (Bioassays)

Water type	% Survival	Mean Shell Length (mm) (\pm SD)	Mean Dry Tissue Weight (mg) (\pm SD)
<i>Lake George (n= 160)</i>	85.6	9.39 \pm 0.13*	43.29 \pm 1.59*
<i>Artificial Water (n= 51)</i>	49.0	9.92 \pm 0.25*	48.79 \pm 3.14*
<i>Hudson River (n= 117)</i>	79.05	10.53 \pm 0.15	65.93 \pm 2.41

**Indicates a Significant Difference ($P < 0.05$) Between Experimental Treatment and Hudson River Treatment*

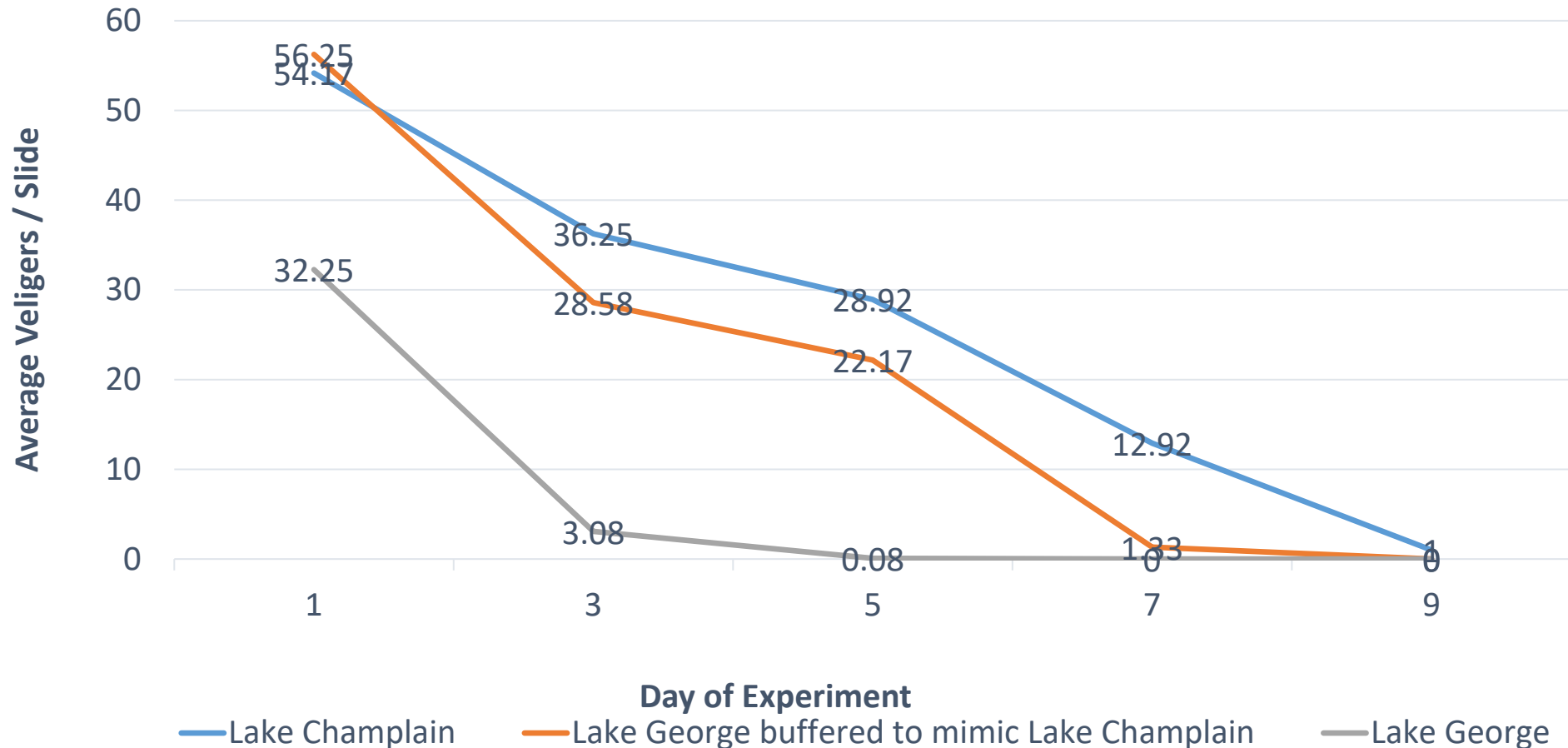
Adults can survive and grow in Lake George water

Veliger Survival in Lake George and Lake Champlain Waters after 9 days



Veligers do not survive in Lake George water

Manipulating pH and Calcium in Lake George Water to Mimic Lake Champlain



Lessons Learned & Recommendations



- Early detection & continuing monitoring critical
- Stakeholder involvement is essential
- Response team & action plans in place
- Prevention & eradication possible (but it helps if water body is sub-optimal)
- Models (based on Ca & pH) useful, but bioassays recommended
- Be prepared for surprises, if its not zebra mussels it might be something else

Collaborators

- Local volunteers, businesses and organizations
- Scientific divers (Scientific Diving International, InnerSpace Scientific Diving, Bateaux Below)
- Local Dive shops (Capitaland SCUBA, Morins Professional SCUBA Centers)
- Commercial Marinas
- Town of Bolton Landing and Village of Lake George
- DFWI scientists, staff and students
- Funding sources: New York Sea Grant, Helen V. Froehlich Foundation, Lake George Watershed Conference, FUND for Lake George

HONORABLE MENTION

- | | |
|---------------------|---------------------------|
| • Bob Benway | • Janet Klemm |
| • Sam Bowser | • Dan Marelli |
| • Chuck Boylen | • Meredith Mccomb |
| • Shary Braithwaite | • Brian McGrath |
| • Larry Eichler | • Sandra Nierzwicki-Bauer |
| • Jeremy Farrell | • Steve Resler |
| • John Farrell | • Geoff Sowan |
| • Marc Frischer | • Paul Vescio |
| • Zandy Gabriels | • Josh Walonowski |
| • Lisa Hall | • John Wimbush |
| • Andy Hansen | • Joe Zarzinski |
| • Alan Humphries | |