



Invasive Species Success Stories – They Exist!

Honorary cosponsors of this briefing are Senate Great Lakes Task Force Co-Chairs Senator Mark Kirk, Senator Debbie Stabenow, Senate Vice-Chairs Senator Rob Portman, Senator Amy Klobuchar, House Great Lakes Task Force Co-Chairs Congresswoman Miller, Congresswoman Kaptur, Congressman Duffy, & Congresswoman Slaughter, and House Invasive Species Task Force Co-Chairs Reps. Dan Benishek and Mike Thompson

Thursday, April 16, 2015

Longworth House Office Building, Room 1310

10:00 a.m.

Speakers:

Marc Gaden, Great Lakes Fishery Commission
Leon Carl, U.S. Geological Survey

Although the constant mantra regarding invasive species has been doom and gloom, through coordination, research, and federal support, the Great Lakes are leading the way with solutions to manage and remove invasive species. Speakers will discuss their efforts, partnerships, and achievements in finding ways to control, though not eradicate, invasive species. They will provide staff background on invasive species efforts regarding sea lamprey, which at one point devastated the lake trout fisheries in the Great Lakes. Speakers will also discuss efforts targeted at the zebra and quagga mussels, which after entering the US through the Great Lakes have spread throughout the country, down the Mississippi River and out to the western states, threatening drinking water, fisheries, industries, and endangered species. Though prevention and early detection are still the most cost-effective methods to invasive species management, the region's scientists and managers have made strides to further combat these two species.

A webinar option is available by registering [here](#).

SEA LAMPREY CONTROL IN THE GREAT LAKES: A REMARKABLE SUCCESS!



MARC GADEN

Great Lakes Fishery Commission, Legislative Liaison



**Great Lakes Task Force Seminar and Webinar
Northeast-Midwest Institute**

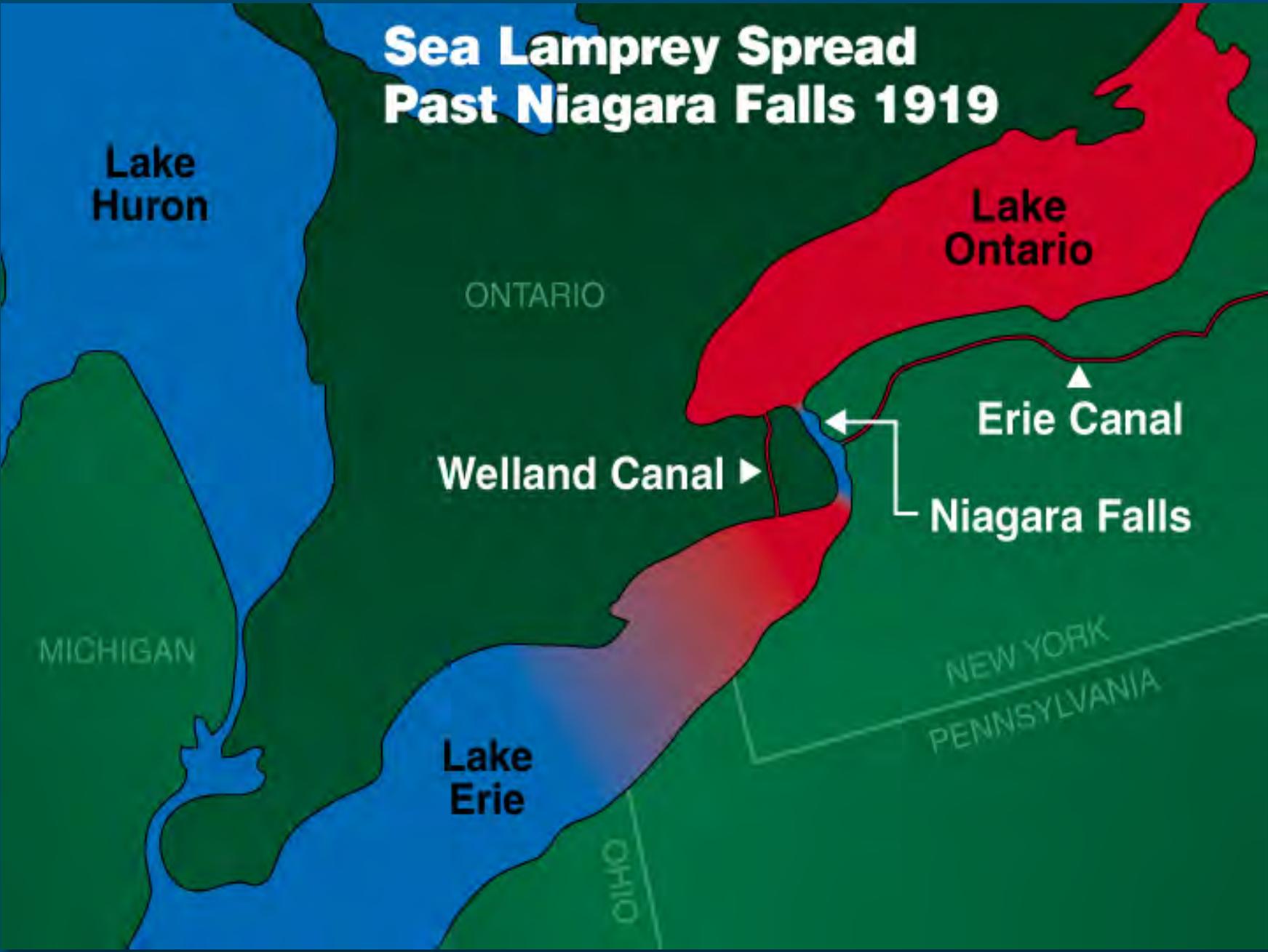
April 16, 2015



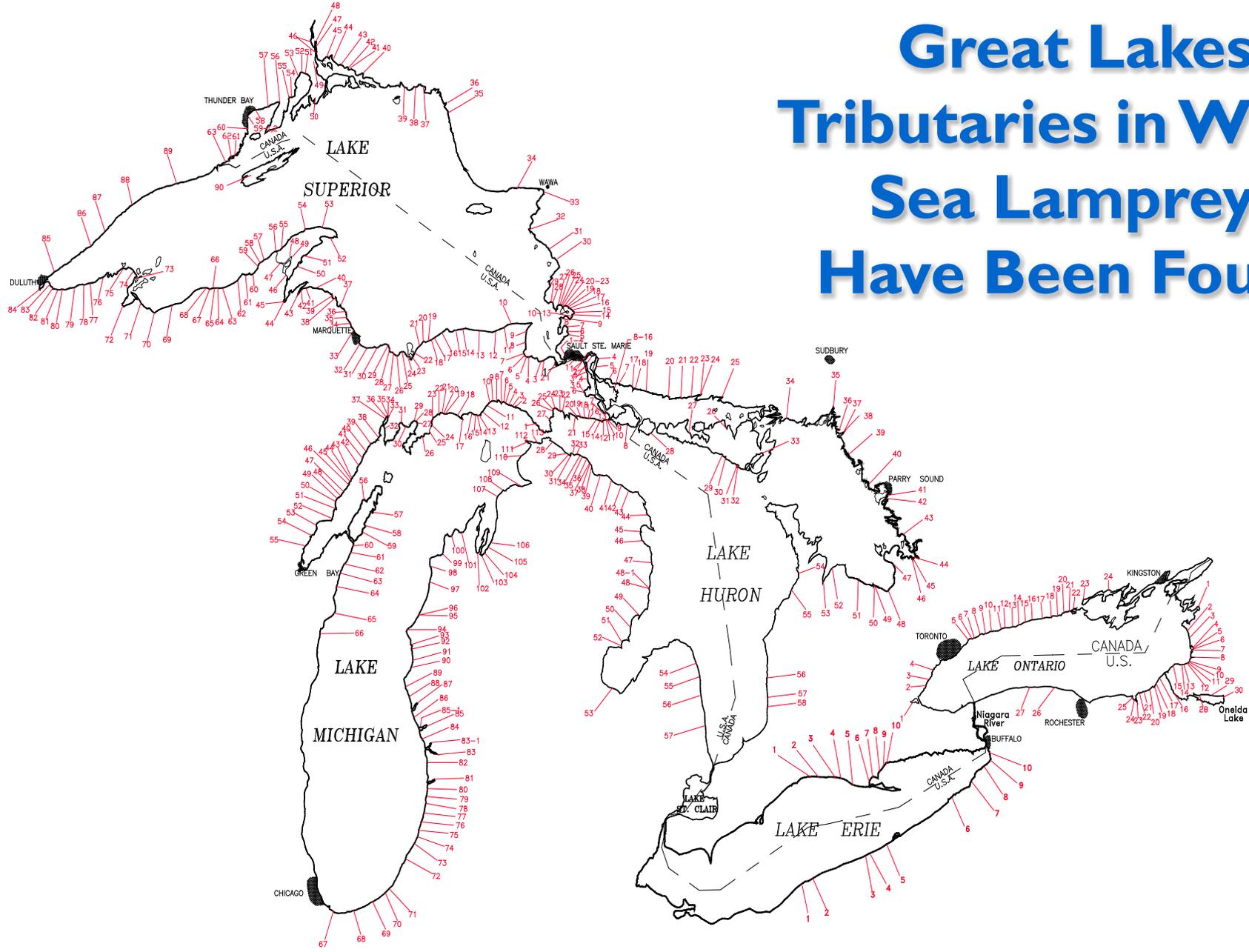
Photos: M. Gaden, T. Lawrence, M. Ryan



Sea Lamprey Spread Past Niagara Falls 1919



Great Lakes Tributaries in Which Sea Lampreys Have Been Found

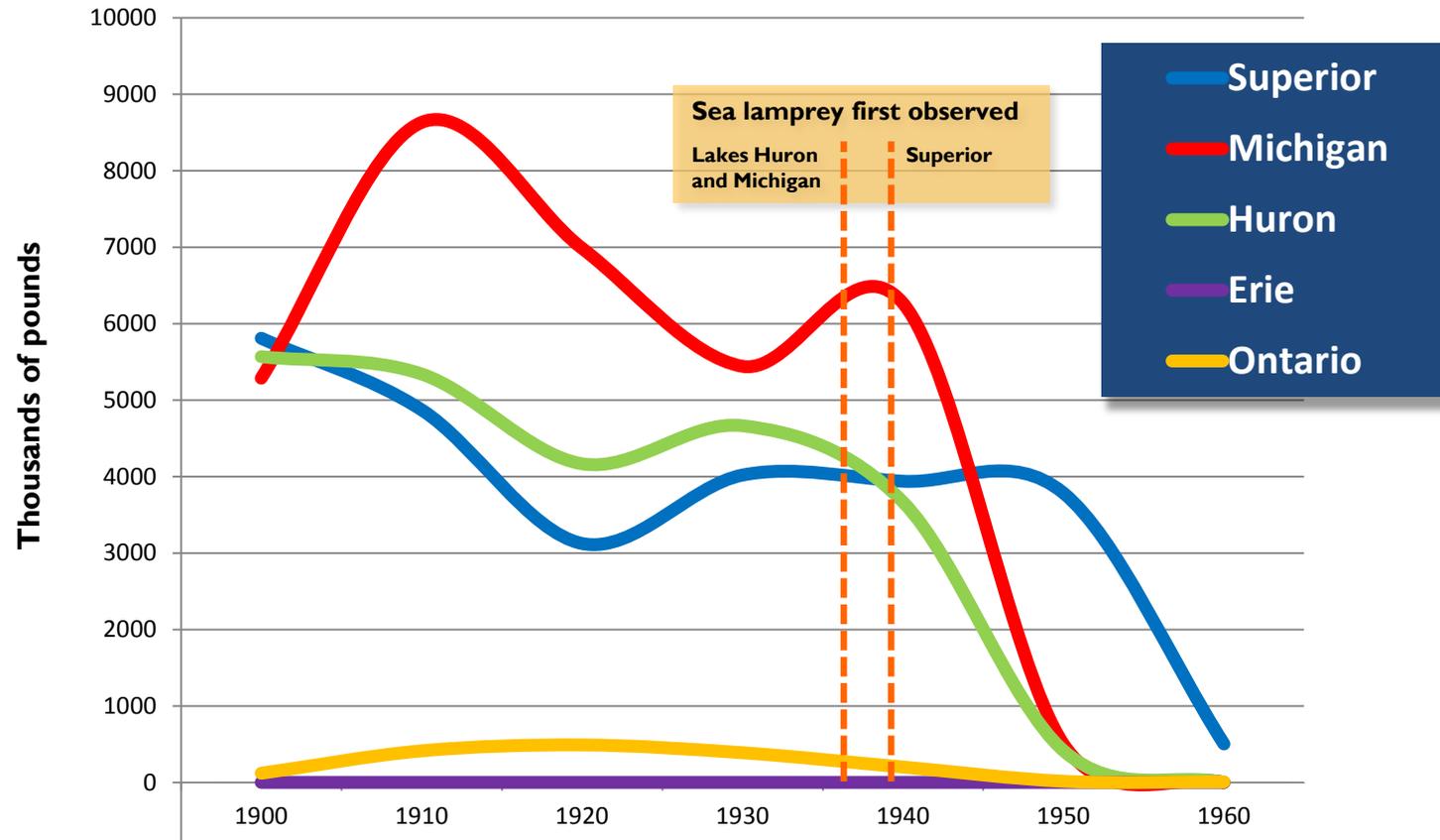






Sea Lamprey: A Devastating Invader

Commercial Lake Trout Harvest





Dear Congressman Potter:

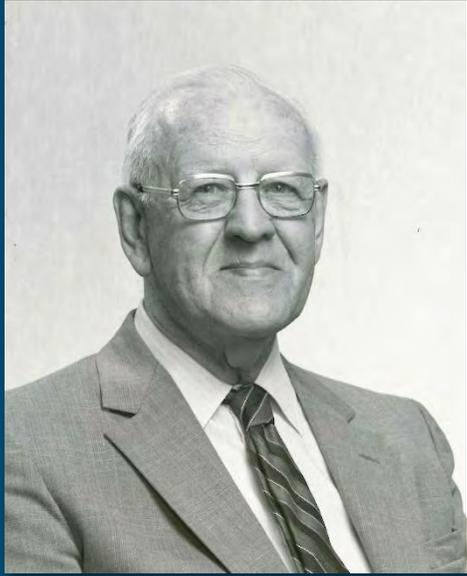
I received your letter of February 25 [1939] and am very pleased to know that something is going to be done to try to control the lamprey eel. I do not believe there is another fisherman on the Great Lakes who has suffered as great a financial loss as I have because of the eel.

–Walter J. Scott, Scott Fishery, Alpena, MI, March 3, 1939

GREAT LAKES SEA LAMPREY CONFERENCE
November 14 and 15, 1946, Ann Arbor, Michigan

- Hoop nets
- Flumes, metal sheets, etc.
- Electric screens
- Trawlers
- Electric shocker
- Dredges
- Capture of metamorphosed lamprey
- Commercial fishing
- Chemicals





To Senator Hubert Humphrey, Chair of the Subcommittee
on the Great Lakes Fisheries Convention

My Dear Senator: We believe that a program to control
the sea lamprey and rehabilitate our fisheries cannot
succeed unless carried out simultaneously by both
countries. . . . Work that is carried out in this country will
be useless coordinated with a similar effort on the
Canadian side of the lakes.

*--Claude VerDuin, Managing Director of the Federation of Freshwater Fisheries, April 25,
1955*

CONVENTION ON GREAT LAKES FISHERIES (1954)

Great Lakes Fishery Convention Act  Great Lakes Fisheries Act



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- Capture of metamorphosed lamprey
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- **Chemicals**





MAJOR SEA LAMPREY CONTROL METHODS

Lampricides



A Binational Program



U.S. Geological Survey



U.S. Fish and Wildlife Service



Fisheries and Oceans Canada



U.S. Army Corps of Engineers

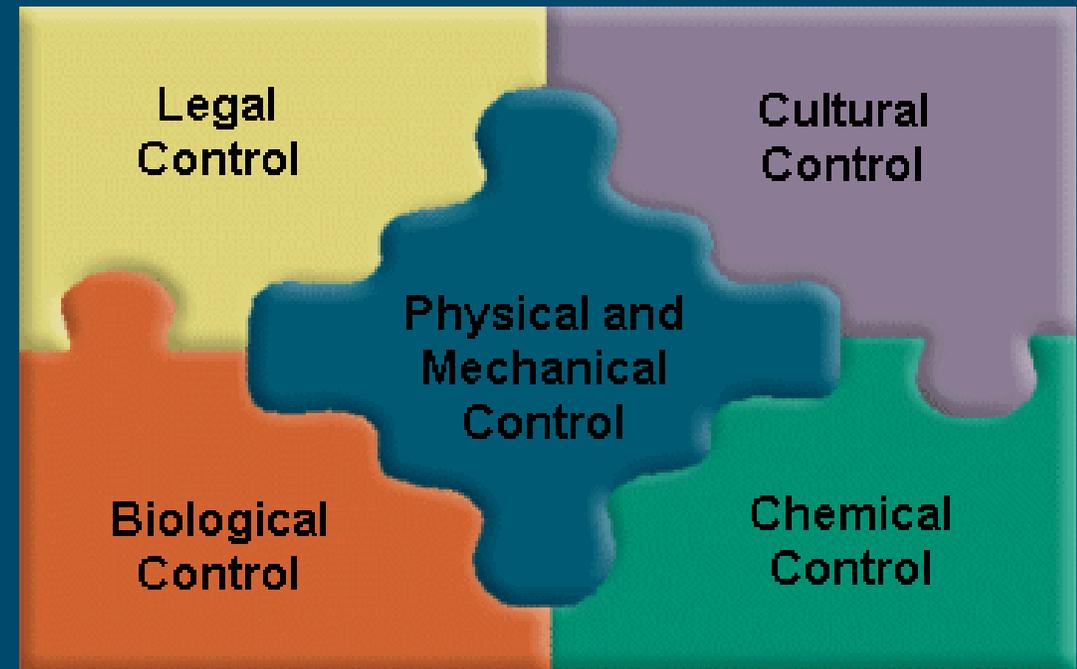


MAJOR SEA LAMPREY CONTROL METHODS

Integrated Pest Management

“Integrated Pest Management (IPM) . . . relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information . . . is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment.”

--U.S. EPA



MAJOR SEA LAMPREY CONTROL METHODS

Lampricides

Barriers



A Binational Program



U.S. Geological Survey



U.S. Fish and Wildlife Service



Fisheries and Oceans Canada



U.S. Army Corps of Engineers

MAJOR SEA LAMPREY CONTROL METHODS

Lampricides

Barriers

Traps



A Binational Program



U.S. Geological Survey



U.S. Fish and Wildlife Service



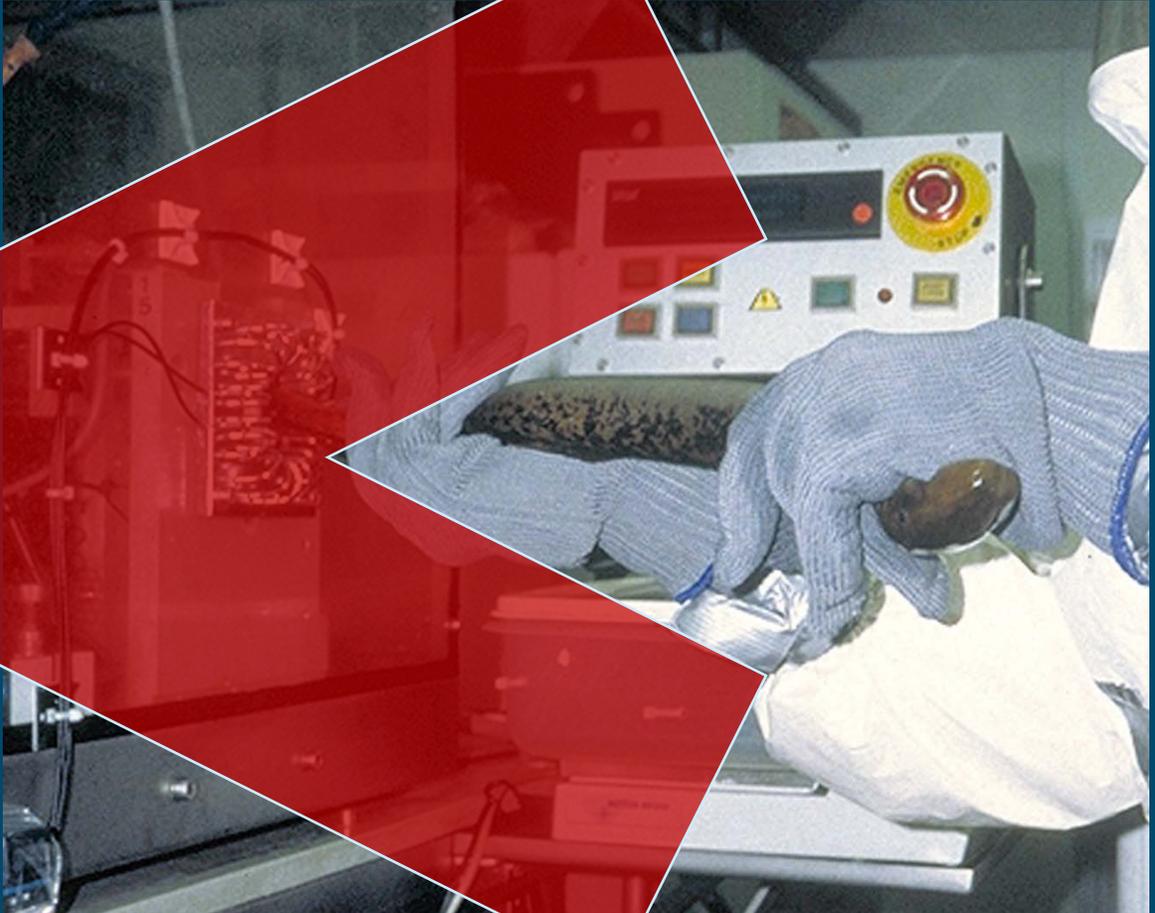
Fisheries and Oceans Canada



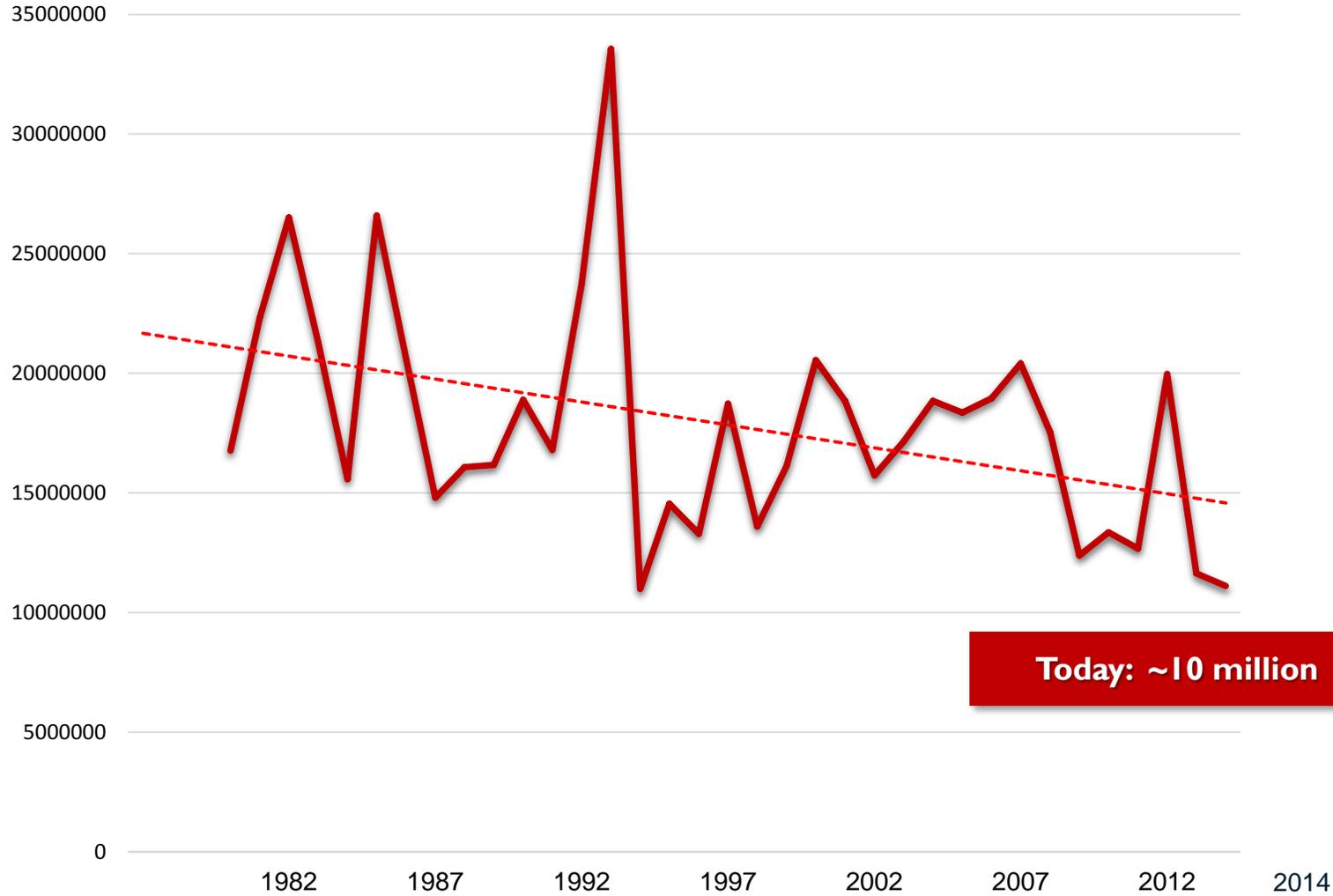
U.S. Army Corps of Engineers

MAJOR SEA LAMPREY CONTROL METHODS

Sterile-male-release



Pounds of Great Lakes fish killed annually by sea lampreys



Pre sea lamprey control:
103 million pounds
of fish killed per year.



PHEROMONES = BEHAVIORAL MODIFICATION



Lampricide Resistance Workshop, December 13, 2014



LESSONS OF THE LAMPREY

- Put someone in charge
- Be binational
- Embrace integrated pest management
- Don't be afraid to innovate
- Don't be afraid to fail
- Control takes money
- The fishery is worth it!
- Prevention is key!



THANK YOU





Invasive Mussel Control - Building on Success

Dr. Leon M. Carl

USGS Midwest Regional Director

Briefing: Invasive Species Success Stories – They Exist!

April 16, 2015

From Sea Lamprey to Asian Carp... Collaborative Response



Asian Carp Regional Coordinating Committee

“The ACRCC, with support from Federal, state, and local agencies, and private stakeholders and citizens, are creating a sustainable Asian carp control program to prevent the establishment of an Asian carp population in the Great Lakes.”

Integrated Pest Management Approach

Integrating the tools, knowledge, and information we have to:

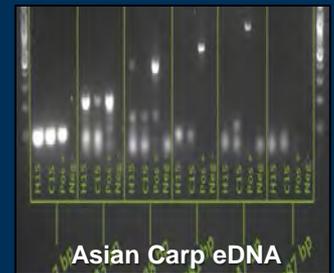
- Detect
- Aggregate
- Remove
- Control and Exclude Asian Carp



Successful IPM effort on upper Illinois River with IL DNR, FWS, SIU integrated waterguns, attractants, fish telemetry and commercial fishing

USGS Control Tool Development – Integrated Cutting Edge Science

- Focus on Asian carp Life Cycle and Biology for integrated control tool development:
 - Microparticles
 - Waterguns
 - CO₂
 - Attractants
 - Risk Assessment and Early Detection

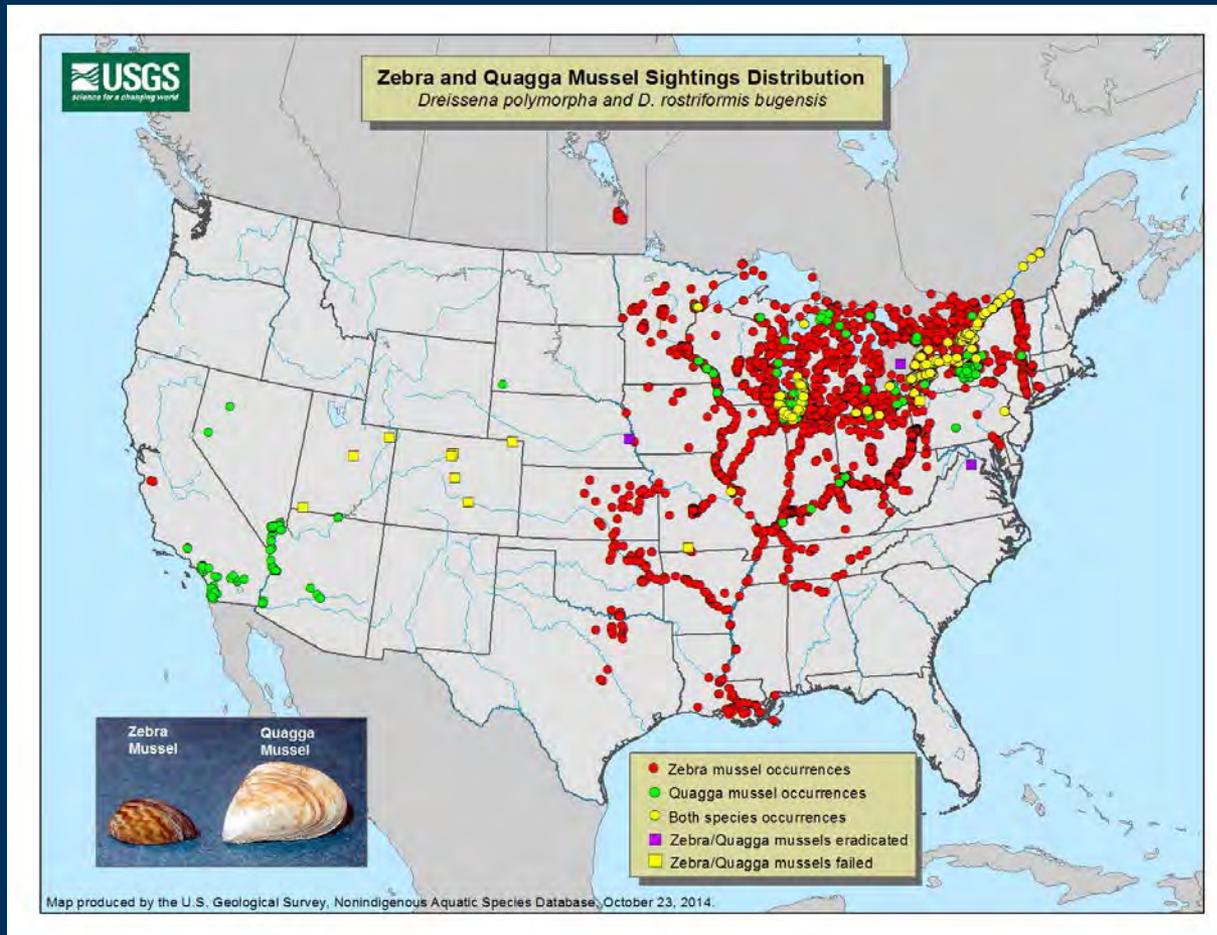


Three Asian Carp Tools Under Development

- **The Microparticle: A coated toxin**
 - The design of the microparticle is based on Asian carp biology; When and where to apply is based on food and habitat preferences or life cycle needs
- **Waterguns – use as a mobile barrier**
 - Field tests showed fish avoid the waterguns – testing new, faster firing waterguns
 - Partners to identify other application sites
- **Hand Held eDNA Kit**
 - Law Enforcement Use: Detect carp in bait shops and live fish shipments
 - Detect scope of species invasion

From Asian Carp to Invasive Mussels...

An International Issue



Effects of Zebra and Quagga Mussels

- Highly negative impacts to food webs (e.g. reductions in pelagic productivity)
- Impacts on infrastructure
- Scope of problem – Huge – Can we control at large scale?
- What would it cost?
- What are the benefits? Economic and Ecological



Control Tool Development: About Zequanox®

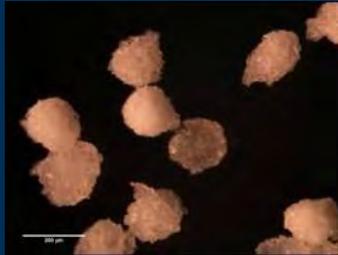


- Discovered by NY State Museum researchers
 - Killed-cells of soil bacterium; now commercial product
- **USGS Findings: Highly selective (So Far)**
 - Non-target animal studies
 - No observed effects on native species tested
 - Targeted studies - Mobile lab - 82-99% mortality
- Next Steps: Refine Zequanox application, dosing, & environmental effects for open water applications
- *Is large scale (lake level) application possible and cost effective?*



USGS Control Tool Development - Toxic Cocktail:

Zequanox® +



Toxic Microparticles

=



Zebra Mussel Mortality

- **Develop and evaluate various microparticle formulations for zebra/quagga mussel control**
 - **Concurrent with Asian carp microparticle development**
- **Evaluate various agents for use in microparticles**
- **Evaluate microparticle efficacy and safety as a control tool**
- **Reduce possibility of resistant population**

Beginning the Collaboration:

- Recent EPA Approval of Zequanox®¹ – a new biological control tool – potentially for open water use
- Partners recognized need for collaborative approach

Modeling Success: Formation of the Invasive Mussel Collaborative



About the Invasive Mussel Collaborative:

- National in scope – Focus on the Great Lakes
- Mission: Advance scientifically sound technology for invasive mussel control to produce measurable ecological and economic benefits.
- Collaborative Approach (Collective Impact)
 - Act expeditiously
 - Work efficiently
 - Work cost-effectively

Invasive Mussel Collaborative: Reaching Out to Partners

Founding Members:

Great Lakes
Commission

Great Lakes Fishery
Commission

National Oceanic and
Atmospheric
Administration

U.S. Geological
Survey

Membership open to:

U.S. and Canada

Federal, Tribal, state
and provincial
agencies

Nongovernment
organizations

Industry

Academia

External Connections:

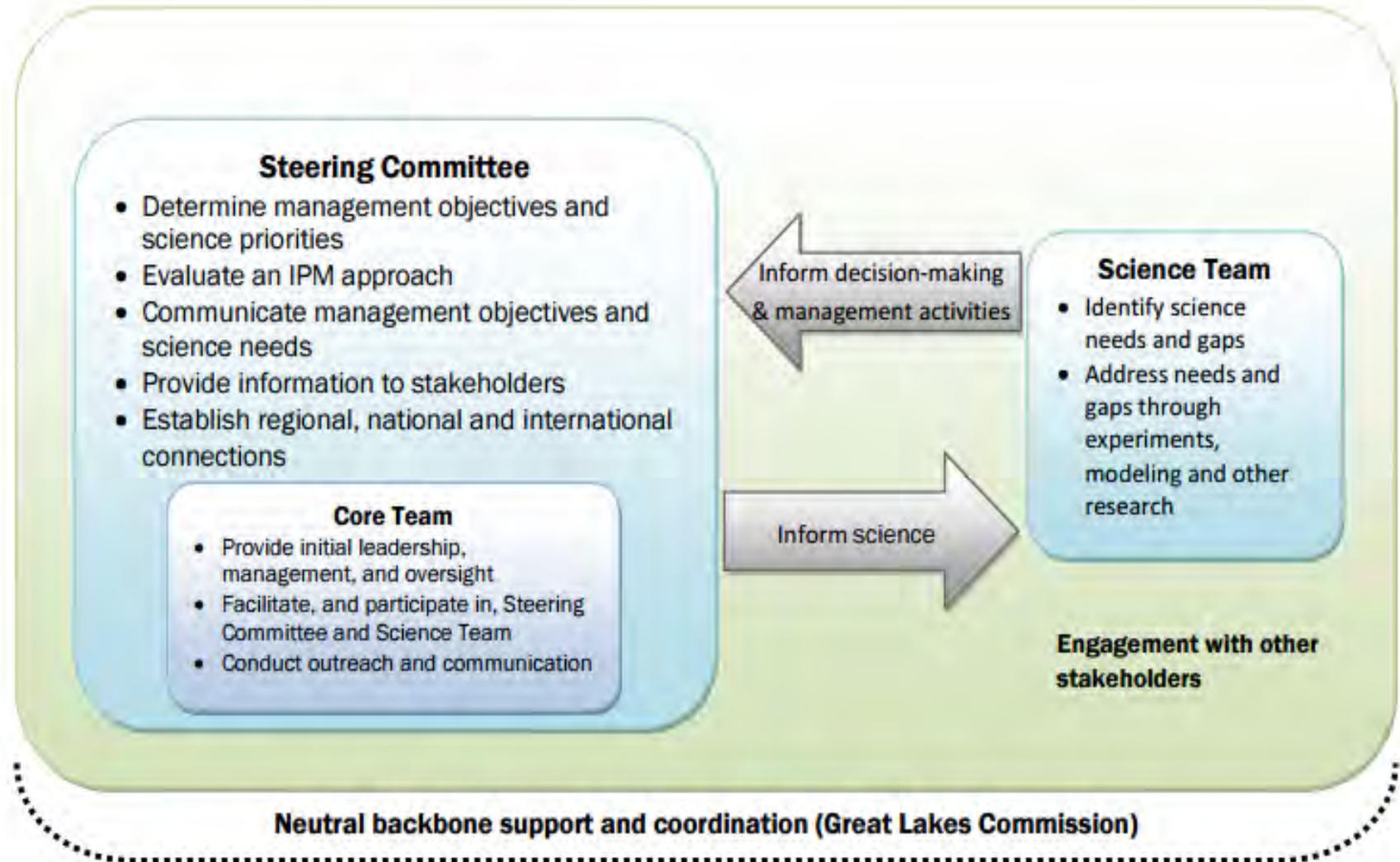
Western U.S. and
other regional groups

Other national and
international
stakeholders

Local groups (e.g.,
lake associations)

Reclamation, U.S.
Congress

IMC Structure



IMC Progress to Date

- Developed prospectus describing IMC
- Held Informational webinar on Dec 1, 2014
- Conducted stakeholder survey for preliminary input on interests/priorities
- Set-up website: *invasivemusselfcollaborative.net*
- Ongoing outreach to stakeholders, regionally, nationally and internationally
- Held first Steering Committee Meeting Feb 5/6, 2015
- Next steps: Formation of Science Team; Steering Committee meeting follow up/actions



Core Team:



IMC Control Tool Development: Addressing Management Priorities

Role of the IMC Science Team: Inform decision-making and management activities. Broad topics - examples:

- Effectiveness, cost efficiency, and Zequanox application issues
- Economic issues (infrastructure; commercial/recreational/tourism)
- Ecosystem issues (foodweb changes and fishery production; HABs link)
- Science focus examples:



Develop models and decision support tools

Understand ecosystem effects

Develop and refine management strategies

Linking with the West

USGS/Reclamation Invasive Mussel Science – Avoid Duplication!

A joint approach to:

- Link scientific expertise across the nation to effectively address management priorities through cutting edge science
- Build and strengthen partnerships through the new Invasive Mussel Collaborative
- Use an Integrated Pest Management approach to strategically develop and apply control tools
- Develop common goals, strategies, and metrics

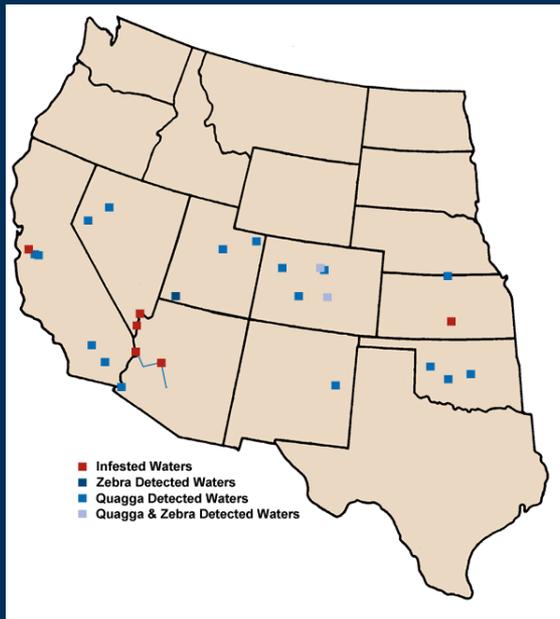
 ***Address Ecosystem and Infrastructure***



RECLAMATION

Managing Water in the West

- **Success in the West: Monitoring, early detection and research for control of invasive zebra and quagga mussels to:**
 - Ensure effective delivery of water and power generation in the western U.S.
 - Understand ecosystem impacts
- ***Monitoring over 200 water bodies, including 160 Reclamation reservoirs, in partnership with western states and agencies***



Reclamation Science Highlights

- Conducted facility assessments to determine potential mussel impacts (e.g. water and power facilities)
 - Proactively addressed operation and maintenance actions in advance of potential infestation
- Developed intensive invasive mussel detection and monitoring program for western waters
- Created baseline data on zooplankton and nutrients to address foodweb impacts in western waters
- Published report on controlling invasive mussel attachment to water and power facilities

An Integrated Pest Management Approach

Reclamation Mussel Control Studies

- Zequanox® Initial studies with MBI on formulations at Davis Dam on Colorado River
 - Toxicity studies
 - Efficacy studies
- Microfiltration testing at Parker Dam
- UV testing at Hoover and Davis Dam
- Turbulence testing at Davis Dam

Continuing the Control Success!

- Continue the success of the Sea Lamprey Program and Asian Carp Control Strategy Framework
- Building the Invasive Mussel Collaborative partnership
 - Linking management objectives and science to take efficient and effective action
- DOI support – Move forward on USGS/Reclamation joint invasive mussel science strategy
- Ultimately, can we control quagga and zebra mussels and at what cost?

Thank you

Before

Sea Lamprey Control

Sea lampreys caused massive fish die-offs that fouled beaches and made shorelines undesirable places to live. Local economies and communities suffered tremendously.



Sea lamprey predation destroyed the fishery.



Shoreline communities fell into decay; tourists stayed away.

GREAT LAKES FISHERY COMMISSION Importance of the Program



After Sea Lamprey Control



Beaches and shorelines today attract residents and tourists.

Fish provide economic benefits and support communities.

Fish lure millions of anglers and provide \$7 billion annually to the region.

The Great Lakes Fishery Commission Delivers!

The sea lamprey control program is essential to the people of the basin.



GREAT LAKES FISHERY COMMISSION

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www.glfc.int



The Great Lakes depend on sea lamprey control The Great Lakes fishery is worth \$7 BILLION annually to the people of the region

- Sea lamprey control is a major reason why the fishery is worth \$7 billion. Control is achievable, but it must be sustained.
- The Great Lakes Fishery Commission's budget is needed to carry out its program to protect and improve the Great Lakes fishery.
- State, provincial, and tribal governments depend on the commission's program to protect the hundreds of millions of dollars they invest in the sport, commercial, and tribal fisheries, comprising species like trout, salmon, walleye, and yellow perch.
- Major funding reductions would eliminate large portions of the sea lamprey control program, resulting in an immediate, significant economic and ecological impact in the Great Lakes region and setting back fishery restoration by decades.

FISH make the lakes great!

Fish are part of the fabric of the Great Lakes region and the fishery is the bedrock of local economies.

- The fishery supports more than 75,000 jobs, in addition to the hundreds of thousands of jobs related to tourism, navigation, and other economic drivers in the region.
- More than 5 million people fish the Great Lakes annually; the region has more than 4 million registered boats, many of which are used for fishing.
- Commercial fishing is the backbone of many Great Lakes communities. Charter fishing is an important business throughout the basin.
- Tribal fishing occurs in large portions of the Great Lakes and is integral to Native communities.



People throughout the Great Lakes basin depend on the fishery for income, recreation, and sustenance. The Wilcox Fish House, run by Ralph and Shirley Wilcox, has been a pillar of the Brimley, Michigan community for decades. The Wilcoxes fish Lake Superior for whitefish and lake trout, which they serve in their restaurant to locals and tourists alike.



SEA LAMPREYS destroy Great Lakes fish

They are invasive predators that must be controlled.

They attack and kill a wide variety of fish species including trout, salmon, whitefish, walleye, and sturgeon.

The Bad News!

The Good News!

Sea lampreys attach to fish with a suction cup mouth ringed with sharp teeth. With a file-like tongue, the sea lamprey bores through the fish's scales and skin and feeds on the fish's blood and bodily fluids. Only one out of seven fish attacked by a sea lamprey will survive.

WITHOUT CONTROL THE FISHERY IS LOST

SEA LAMPREY CONTROL WORKS!

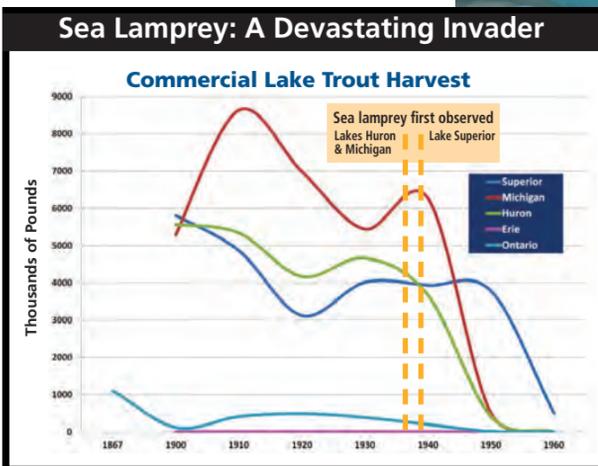
- History shows that with fewer fish, the region's economy and environment suffer greatly.
- Without sea lamprey control, the Great Lakes fishery would not exist as we know it.
 - Each sea lamprey destroys up to 40 pounds of Great Lakes fish.
 - The world-class trout, salmon, and whitefish fisheries would collapse due to sea lamprey predation.
 - More sea lampreys would mean fewer fish and failed restoration.
 - The ecological and economic damage caused by increased sea lamprey abundances would be costly, devastating, and difficult or impossible to reverse.

- Unlike most other invasive species, sea lampreys can be controlled.
- Thanks to committed action by Canada and the United States over the course of five decades, sea lamprey abundances are at or near target levels in many areas of the Great Lakes – **a major success!**
- Low sea lamprey abundances are necessary for restoration of fish like sturgeon, lake trout, ciscoes, and other important species.
- Sea lamprey control has allowed state, provincial, tribal, and federal governments to invest hundreds of millions of dollars in the fishery.

**Control must be ongoing.
Resources are needed
to do the job.**



After sea lamprey entered the system, the harvest of lake trout, the top commercial species in the basin, dropped dramatically.



The Great Lakes Fishery Commission Budget

The commission's budget, as submitted to government, would:

- Allow the delivery of a program that protects the Great Lakes ecosystem and fishery and provides major economic and environmental returns to the people of the region.
- Provide the necessary funds for the commission to control sea lampreys throughout the Great Lakes basin, particularly in areas where sea lamprey abundances are too high.
- Allow the commission to continue to use innovative alternative sea lamprey control techniques, most notably pheromones.
- Allow the commission to complement the Great Lakes Restoration Initiative by helping to restore healthy fisheries that provide billions of dollars in economic return.
- Implement the commission's fishery research program, which contributes to measures used by state, tribal, provincial, and federal fish management agencies to sustain fisheries.

Major reductions to the budget would:

- Jeopardize the Great Lakes ecosystem and \$7 billion fishery and the economic benefits and jobs associated with the fishery.
- Undermine decades of significant effort at all levels of government to achieve restoration of the Great Lakes fishery and the associated economic and ecological benefits.
- Undermine the president's objectives through the Great Lakes Restoration Initiative.
- Significantly reduce or eliminate portions of the essential sea lamprey control program throughout the Great Lakes basin.
- Increase sea lamprey abundances by the hundreds of thousands, which would destroy millions of Great Lakes fish.
- Jeopardize the significant progress made toward native species (e.g., lake trout, sturgeon) restoration during recent years.
- Constrain or end the implementation of innovative alternative sea lamprey control techniques, most notably pheromones.
- Significantly shrink fishery research in areas like invasive species and native species restoration.



State and Foreign Operations Appropriations Bill "International Fisheries Commissions" Section

	Great Lakes Fishery Commission Appropriation	=	Great Lakes	+	Lake Champlain	All International Fisheries Commissions ¹
2015 President's Proposal	19.9		19.9		0	31.4
2015 House						
2015 Senate						
2015 FINAL						
2014	23.7		20.7		3.0	36.0
2013	21.2		18.5		2.7	34.5
2012	23.9		20.9		3.0	36.3
2011	24.3		21.3		3.0	50.5
2010	28.2		21.7		6.5	54.0

All figures in millions of dollars

1. "International Fisheries Commissions" are institutions, established by treaty or agreement, that uphold U.S. commitments to shared fishery resources. The Great Lakes Fishery Commission is one such institution. International Fisheries Commissions appear as a group in the budget.

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Invasive Mussel Collaborative

Invasive zebra and quagga mussels (*Dreissena polymorpha* and *D. rostriformis bugensis*, respectively) are causing significant ecological and economic impacts and the scope of these impacts has increased as they continue to spread from the Great Lakes across North America, from the Hudson River in the east to Lake Mead in the west. They alter ecosystem dynamics and affect industrial, municipal and recreational water users. The negative impacts of these dreissenid mussels drove scientists to search for effective control methods beginning in the early 1990s. That search took a dramatic step forward when scientists from the New York State Museum Field Research Laboratory discovered that the killed-cells of a specific strain (CL145A) of a common soil bacterium, *Pseudomonas fluorescens*, caused mortality in dreissenid mussels with limited non-target animal impacts based on testing conducted to date. A second dramatic step forward was the registration and approval by the U.S. Environmental Protection Agency of the commercial product Zequanox® (containing *P. flouorescens* CL145A as the active ingredient) for use in open water environments.¹



Effects of biocontrol application

A colony of zebra mussels attached to a native mussel. The native mussel survives the application of biocontrol; the zebra mussels do not.

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New biocontrol technology represents an exciting potential technique to manage invasive mussels. In light of this new opportunity, diverse management goals must be identified and understood and knowledge gaps addressed in order to move forward with a joint and strategic approach to managing invasive mussels. Further investigation is needed to address uncertainties in the use of biocontrol, such as potential effects on invertebrates and ecosystems, and optimal application procedures. In addition, the coordinated and integrated application of several different control tools has been proven to yield the most effective control strategy for other invasive species. Consequently, research should continue to identify the next set of control tools (e.g., spawning inhibitors and microparticles to target control agent delivery). Ideally, managers and scientists would have a forum in which to communicate and coordinate this work using an iterative and collaborative process.

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A Collaborative Approach

The **Invasive Mussel Collaborative** is being established to advance scientifically sound technology for invasive mussel control to produce measurable ecological and economic benefits. The Collaborative will provide a framework for communication and coordination, identify the needs and objectives of resource managers, prioritize the supporting science, recommend communication strategies, and align science and management goals into a common agenda for invasive mussel control.

The founding members of the collaborative are the U.S. Geological Survey, Great Lakes Commission, National Oceanic and Atmospheric Administration and the Great Lakes Fishery Commission. The Great Lakes Commission will provide coordination and neutral backbone support for the collaborative. A broad membership base of states, provinces, tribal and other entities and a well-organized communication network will facilitate the exchange of information between scientists, managers and stakeholders, and provide ongoing guidance and feedback within an adaptive management framework. Strong connections with other regions will be developed and will provide a framework for application elsewhere.

Founders

- Great Lakes Commission
- Great Lakes Fishery Commission
- National Oceanic and Atmospheric Administration
- U.S. Geological Survey

Members

- U.S. and Canada Federal, Tribal, state, provincial and local agencies
- Nongovernment organizations
- Industry
- Academia

External Connections

- Local groups (e.g., lake associations)
- Other regional groups (e.g., Western U.S.)
- Other national and international stakeholders

¹ Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

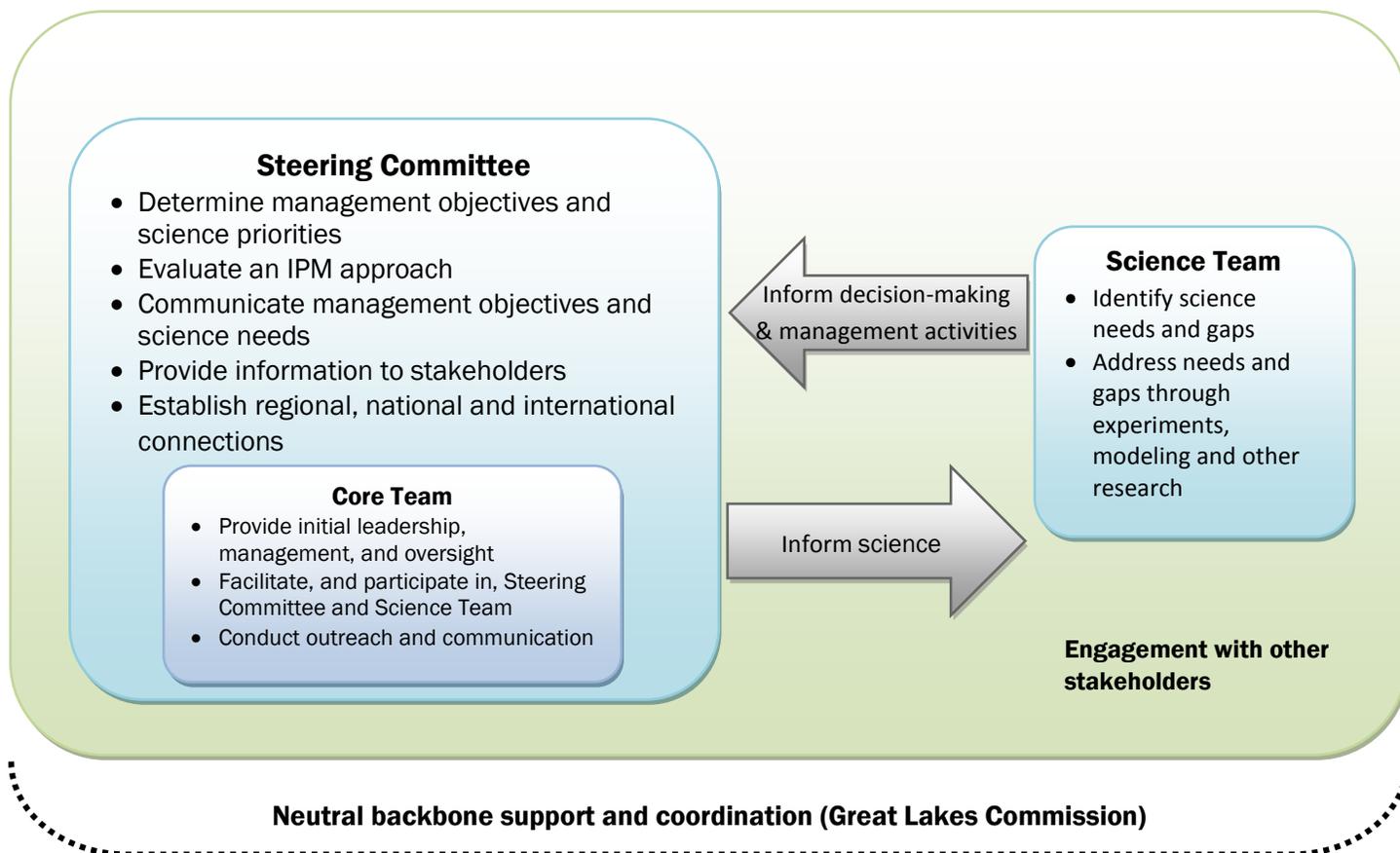


Invasive Mussel Collaborative

Mission: Advance scientifically sound technology for invasive mussel control to produce measurable ecological and economic benefits.

Objectives:

- Facilitate information exchange between decision-makers, scientists and stakeholders
- Develop and guide a joint and strategic approach to invasive mussels
- Implement communication and outreach activities



Example science questions. These examples of science questions related to dreissenid mussels are expected to be modified as the collaborative process matures and updates critical management objectives and science information gaps.

Develop models and decision support tools

- Develop population models for quagga mussels
- Predict how dreissenid population growth would vary with different control strategies
- Develop models to assess effects of varying levels of control on ecosystem services, including risk assessments

Understand ecosystem effects

- Determine the relationship between dreissenid mussels and harmful algal blooms
- Determine the effect of dying and dead mussels on oxygen and nutrient concentrations, and the surrounding microbial and invertebrate community
- Determine whether dreissenid mussels affect fish populations

Develop and refine management strategies

- Optimize biocontrol application procedures
- Continue development of additional control tools
- Assess and understand the direct effects of control strategies, including biocontrol, on native and non-target species

Current and Recent USGS/Reclamation Invasive Mussel Research Activities

Monitoring & Detection

DNA-Specific Studies – Potential Collaborative Opportunities:

- **Depth profile sampling for determining the optimal water column location for detection of zebra mussel environmental DNA (U.S. Geological Survey)** - This research investigated depth profile sampling on Lake Minnetonka over an existing dreissenid mussel colonies. Water samples were collected on the surface, mid-water column, and near the benthos to determine the optimum sample location to produce the greatest rate of detection. This research will inform future dreissenid environmental DNA sampling efforts. This research is currently being supported by the Legislative-Citizens Commission on Minnesota Resources and USGS appropriated funds. *USGS Contact:* Dr. Jon Amberg (jamberg@usgs.gov)
- **Correlation of zebra mussel environmental DNA (eDNA) detection with substrate type in summer and winter months (U.S. Geological Survey)** - Environmental DNA (eDNA) sampling was conducted on low and high dreissenid density lakes (Maple Lake, MN and Lake Le Homme Dieu, MN, respectively) to evaluate the potential use of eDNA to characterize dreissenid mussel distribution in lakes with established and recently introduced dreissenid populations. Specific goals include determining the best sampling location for dreissenid mussel eDNA detection and determining the seasonal (i.e. winter) detection capabilities using eDNA. The project supports research to develop eDNA as a treatment prioritization tool for targeting control tools in an integrated pest management strategy. *USGS Contact:* Dr. Jon Amberg (jamberg@usgs.gov)
- **Early detection of zebra and quagga mussels using Polymerase Chain Reaction (PCR) (Bureau of Reclamation)** – Reclamation has developed and optimized a PCR method that has been applied for confirmation of the presence of zebra and quagga mussels in water samples. One of the advantages of PCR is that it is a highly sensitive method for confirming the presence of mussel DNA in early detection samples. *Reclamation contact:* Dr. Jacque Keeley (jkeele@usbr.gov)

Other Monitoring and Detection Studies:

- **Improvement of optical techniques for the detection of larval mussels (Bureau of Reclamation)**
This project improved methods for detecting zebra and quagga mussels in water samples using microscopy. Researchers utilized scanning electron microscopy (SEM) to validate cross polarization microscopy findings. This research improved confidence of early detection identifications.
Reclamation contact: Denise Hosler (dhosler@usbr.gov)

- **Enumeration method validation for larval mussels (Bureau of Reclamation)** – This project helped develop improved methods and protocols for quantifying the number of larval mussel veligers in water samples. These methods continue to assist response planning efforts by providing accurate information on level of infestation. *Reclamation contact:* Denise Hosler (dhosler@usbr.gov)
- **Impact of Sample Preservation on the Detection of Invasive Mussel Larvae by Microscopy and PCR (Bureau of Reclamation)**- Early detection of dreissenid veligers is difficult because the organisms are microscopic and sensitive to degradation. The goal of this research was to further investigate how sample preservation impacts detection of mussel larvae by cross polarized light microscopy (CPLM) and polymerase chain reaction (PCR). This study tested the impact of eight sample preservation scenarios on veligers in reservoir water. *Reclamation contact:* Denise Hosler (dhosler@usbr.gov), Sherri Pucherelli (spucherelli@usbr.gov), and Dr. Jacque Keele (jkeele@usbr.gov)
- **Habitat Suitability Parameters for Invasive Mussels at Reclamation Managed Facilities and Waters (Bureau of Reclamation)**- The majority of the body of literature that describes our current understanding of the water quality parameters associated with dreissenid mussel habitat suitability is related to studies and distributional records of zebra mussels. However, quagga mussels are the dominant species infesting Western water bodies, and there is evidence that this species has different tolerances for certain environmental conditions than zebra mussels. This study examines habitat suitability in the lower Colorado River System to explain observed mussel settlement variation. *Reclamation contacts:* Scott O’Meara (someara@usbr.gov) and Sherri Pucherelli (spucherelli@usbr.gov)

Control

Zequanox[®] Control Studies – Potential Collaborative Opportunities:

- **Field trials using *Pseudomonas fluorescens* (Bureau of Reclamation)** – Reclamation developed a Cooperative Research and Development Agreement with Marrone Bio Innovations (MBI), to conduct a field demonstration of ZequanoxTM, a bacterial product made from dead *Pseudomonas fluorescens*, for controlling adult quagga mussels. This product is lethal only to quagga and zebra mussels, and it potentially offers an environmentally friendly alternative to many conventional molluscicides, and it is expected to have wide-ranging applications for treatment of systems exposed to mussels. *Reclamation contacts:* Denise Hosler (dhosler@usbr.gov) formerly Fred Nibling , & Leonard Willett (lwillett@usbr.gov)
- **Modifications to Davis Dam service water intake to enable field evaluations (Bureau of Reclamation)** – For field testing of Zequanox[®] and other promising treatment methods, it was

necessary to modify the service water intake at Davis Dam to isolate service water system. Under this same project, Reclamation took the opportunity to demonstrate the effectiveness of high pressure water jetting for cleanout of a heavily infested service water line. This project was completed in December 2008. *Reclamation contacts:* Dr. Allen Skaja (askaja@usbr.gov) & Aaron Muehlberg (amuehlberg@usbr.gov)

- **Expanded evaluation of Zequanox (U.S. Geological Survey)** - This project involved expanding the knowledge Zequanox exposure-related effect to non-target animals by conducting exposures in outdoor mesocosms with two species of native aquatic invertebrates, scuds (*Gammarus lacustris*) and mayflies (*Hexagenia* sp). Potential effects of Zequanox on the reproduction of fathead minnows (*Pimephales promelas*) is also under investigation. Spawning adults and newly spawned eggs were exposed to Zequanox in 2014 and the resulting fry have been monitored for growth and survival. Continued work will be conducted during the 2015 field season to evaluate the effects of Zequanox exposure to the early lifestage of fathead minnows. This project also evaluated Zequanox open-water application techniques using 27-m² in-lake enclosure applications to reduce the amount of Zequanox necessary to achieve dreissenid mussel control. *USGS Contact:* Dr. James Luoma (jluomo@usgs.gov)
- **Evaluation of Zequanox[®] for native mussel conservation (U.S. Geological Survey)** - USGS conducted research to evaluate the effects of Zequanox exposure on non-target animals including three lifestages of native unionid mussels and eight species of freshwater fish. Field studies were conducted to determine the efficacy of Zequanox for controlling dreissenid mussels in open-waters (mobile laboratory applications) and its effectiveness for removing invasive mussels from native unionid mussels (In-lake enclosures applications). *USGS Contact:* Dr. James Luoma (jluomo@usgs.gov)

Other Control Studies:

- **Antifouling and foul-release coatings evaluations (Bureau of Reclamation)** – In partnership with Reclamation’s LC Dams Office various commercially available protective coatings are being evaluated at Reclamation’s Parker Dam. While this study is expected to expand in scope and continue for several years, promising coatings solutions are being identified and our current understanding regarding the effectiveness of different coatings systems in the context of invasive mussel fouling has improved. *Reclamation contact:* Dr. Allen Skaja (askaja@usbr.gov)
- **Filtration evaluations at Parker and Hoover Dams (Bureau of Reclamation)** – Although filtration has limited application due to the relatively low capacity, there are many situations where filtration appears promising. Reclamation researchers, in partnership with Reclamation’s LC Dams Office, are evaluating 40- and 80-micron self-cleaning filtration systems developed for ballast water applications. The purpose is to demonstrate the practicality and effectiveness of filtration in either excluding or

preventing settlement in water supply lines and cooling water systems. The added advantage of filtration is that it eliminates the need for conventional oxidizing chemicals. *Reclamation contacts:* Denise Hosler (dhosler@usbr.gov) formerly Fred Nibling, & Leonard Willett (lwillett@usbr.gov)

- **Ultraviolet (UV) treatment evaluations at Hoover Dam and Davis Dam (Bureau of Reclamation)** – Reclamation researchers and RNT Consulting evaluated ultraviolet (UV) light treatment as a means for impeding mussel settlement in water supply lines and potentially power plant cooling water systems. Two UV units were tested, and the impact of several UV doses on veliger mortality and mussel settlement were analyzed. The primary advantage of this treatment method is that it would eliminate the need for conventional oxidizing chemicals and as such it represents an environmentally safe alternative to mussel control. An added advantage of UV is the known effective treatment for other waterborne organisms in drinking water systems. *Reclamation contacts:* Sherri Pucherelli (spucherelli@usbr.gov) & Leonard Willett (lwillett@usbr.gov)
- **Investigation of fish screening technologies to reduce mussel impacts (Bureau of Reclamation)** – Many Reclamation facilities throughout the Western United States have large investments in fish protection facilities. Recognizing the potential future impacts that invasive mussels pose to fish screen facilities, Reclamation is proactively studying promising screening technologies that can operate effectively and efficiently in the presence mussel infestations. To identify and develop solutions for fish screen facilities, Reclamation is currently field-testing commercially available screen systems in mussel-infested water along the lower reaches of the Colorado River. *Reclamation contact:* Cathy Carp (ckarp@usbr.gov) and Josh Mortenson (jmortenson@usbr.gov)
- **Invasive mussel control in pipelines using turbulence (Bureau of Reclamation)**–The main objective of this research project was to determine if turbulence can be used as a viable control to prevent mussel settlement in closed piping systems. Turbulence treatment for the prevention of mussel settlement in cooling lines would be beneficial because it is low maintenance, low cost, widely applicable and could easily be used in conjunction with other methods to enhance performance. *Reclamation contacts:* Joshua Mortensen (jmortensen@usbr.gov) and Sherri Pucherelli (spucherelli@usbr.gov)
- **Controlling mussels with natural predators (Bureau of Reclamation)** – A variety of potential natural predators exist for control of invasive mussel populations. This project seeks, as an initial or scoping level effort, to identify those species that may have application to water delivery systems (e.g., canals) and provide recommendations for future research toward implementation. *Reclamation contact:* Cathy Karp (ckarp@usbr.gov) & Fred Nibling (fnibling@usbr.gov)
- **Evaluation of toxicant incorporated micro-particles for Dreissenid mussel control (U.S. Geological Survey)** - Research will continue to incorporate molluscicidal agents (mussel toxins) within micro-particles to be ingested by invasive mussels in an integrated pest management program.

Work conducted to date has resulted in the incorporation of the toxin niclosamide within micro-particles. Future research will refine the incorporation technique, evaluate toxicant retention in an aqueous environment, and evaluate efficacy of experimental formulations of micro-particles. *USGS Contact:* Dr. James Luoma (jluomo@usgs.gov)

- **Quagga mussel control using copper-ion generators (Bureau of Reclamation)**– The use of copper-ion generators for facilities protection from mussel settlement has been identified as having potential. Through this scoping-level effort, recommendations will be made regarding applicability and value of this technology for future field demonstration. *Reclamation contact:* Roger Turcotte (rturcotte@usbr.gov)
- **Evaluation of electrical fields for control of dreissenid mussels (U.S. Geological Survey)**- This project will evaluate the use of various electrical waveforms (i.e. AC, DC, pulse DC and Pulse AC) to control dreissenid mussels. Low intensity electrical fields have been evaluated for long term deployment use in controlling dreissenid mussels. Research on the use of various electrical waveforms and targeted high-intensity electrical fields for dreissenid control is lacking. This project will determine the minimum lethal threshold and exposure duration required by various electrical waveforms to induce dreissenid mussel mortality. This research will provide the baseline information required to evaluate the potential use of electrical fields for the control of dreissenid mussels in an integrated pest management program. *USGS Contact:* Dr. Mark Gaikowski (mgaikowski@usgs.gov)
- **Characterization of spawning inhibiting cues to control dreissenid mussels (U.S. Geological Survey)**- Experiments have shown that extracts from cultured algae (Chlorella and various marine algae) stimulated zebra mussel and quagga mussel spawning and that treatment of quagga mussels with Microcystis inhibited spawning induced by serotonin, the natural internal activator of spawning in both male and female mussels. The goal of this work is to identify dreissenid mussel control chemicals produced by algae that selectively stimulate or inhibit dreissenid mussel spawning. Objectives include identifying the active components within the algae extracts, describing the environmental and physiological conditions in which they trigger the strongest response, and demonstrating efficacy in mesocosm experiments. This study is being conducted in collaboration with Wayne State University, Detroit, MI. *USGS Contact:* Dr. Nicholas Johnson (njohnson@usgs.gov)

Ecological Impacts

Site-Specific Lake Studies:

- **Lake Ontario Benthic Communities and the Effects of Exotic Mussels (U.S. Geological Survey)**
 - There is a critical need for understanding how Great Lakes benthic productivity has changed and is changing in response to invasive species, particularly quagga mussels (*Dreissena rostriformis*)

bugensis). Through the development of a dreissenid mussel population and biomass time series along with that of the associated native benthic fauna, the food web and ecosystem consequences can be measured and modeled. This benthic community change data set supports similar GLSC fish community long term data sets. *USGS Contacts:* Dr. Dawn Dittman, (ddittman@usgs.gov), Dr. Maureen Walsh (mwalsh@usgs.gov) and Dr. Brian Weidel (bweidel@usgs.gov)

- **Benthic Ecosystem Function of Lake Ontario: Simulation and Community Assessment (U.S. Geological Survey)** - There have been dramatic changes in Great Lakes ecosystems over the past century, particularly since major exotic species invasion (e.g., colonization by dreissenid mussels). Scientists developed a spatially explicit, individual-based theoretical model of the benthic system in Lake Ontario and its links to the pelagic system to examine the dynamics of this ecosystem and effects of the dreissenid mussel and round goby invasions and native fauna losses. Model capabilities to simulate various environmental change scenarios make it a valuable tool to help managers understand the benthic system and plan for future disruptions. *USGS Contacts:* Dr. Dawn Dittman (ddittman@usgs.gov); Dr. James McKenna (dmckenna@usgs.gov)
- **Assessment of the efficacy of dreissenid mussel control in western Lake Erie (U.S. Geological Survey)** - When/if dreissenid-mussel control is initiated in western Lake Erie, there will be need to assess control efficacy inside the target area and compare results to areas located outside the target area. This task can best be done by an existing USGS survey program that has tracked dreissenid abundances at 31 sites throughout western Lake Erie for the last 10 years. This data set will allow for better understanding of the changes of mussel abundances over the period of control activity, and it will also allow better assessment of control activities relative to 'normal' annual fluctuations. *USGS Contact:* Dr. Donald Schloesser (dschloesser@usgs.gov)
- **Dreissenid mussel effects on harmful algal blooms (HABs) (U.S. Geological Survey)** - Assessing the degree to which Dreissenid mussels “multiply” HAB intensity and testing the mechanisms of this effect were recently identified by the Invasive Mussel Collaborative (IMC) Steering Committee as a high priority science need. USGS research is addressing the direct and indirect effects of Dreissenid mussels on HABs through ongoing research including a study of controls on algal species composition leading to HABs initiation and through a new partnership with the University of Michigan and NOAA that is using geo-statistical mapping to explore the spatial correlation of Dreissenid and HABs occurrence over the last 10 years. *USGS Contact:* Dr. Mary Ann Evans (maevens@usgs.gov)

Species-Specific Lake Studies - Potential Collaborative Opportunities:

- **Evaluation of Zequanox applications on nutrient cycling and unionid mussels (U.S. Geological Survey)** - This proposed project will involve the application of Zequanox within replicated benthic chambers (with and without dreissenid mussels present) in order to determine the nutrient dynamics (i.e., nitrogen & phosphorus) resulting from the application of Zequanox and the release of nutrients

from dreissenid mussels killed during the treatments. Furthermore, this project will evaluate potential exposure-related effects to native unionid mussels using sublethal indicators of condition, such as muscle glycogen content. The results and the methods developed in this project will help inform lake managers of the potential ecosystem level effects of dreissenid mussel control tools.

USGS Contact: Dr. Teresa Newton (tnewton@usgs.gov)

- **Evaluation of Zequanox exposure to native trust species (U.S. Geological Survey)** - This project will assess the effects of Zequanox exposures on two native trust species (lake sturgeon [*Acipenser fulvescens*], and lake trout [*Salvelinus namaycush*]). The test fish will be held for approximately 30 days after exposure to evaluate latent effects. *USGS Contact:* Dr. James Luoma (jluoma@usgs.gov)
- **Impact of zebra mussels on the physical, chemical, and biological attributes of Lake Pueblo, Colorado (Bureau of Reclamation)** – In 2008, zebra mussels were detected in Lake Pueblo, Colorado. Having discovered these mussels in the very early stage of infestation affords the opportunity to track limnological changes in the water body as the infestation progresses. This is expected to provide further information regarding the manifestation and ecological impacts attributable to mussels. *Reclamation contacts:* Denise Hosler (dhosler@usbr.gov) & Davine Lieberman (dlieberman@usbr.gov)

River-focused Studies - Potential Collaborative Opportunity:

- **Effects and spread of invasive mussels in lotic environments (Bureau of Reclamation)** – Recent infestations in the Western United States are expected to have significant ecological impacts similar to those experienced in the Great Lakes. However, an improved understanding of those impacts in the West is needed. The findings from this project are expected to highlight issues and assist in future prioritization of actions for mitigating invasive mussel impacts on natural resources. *Reclamation contact:* S. Mark Nelson (snelson@usbr.gov)