19th International Conference on Aquatic Invasive Species

Credit: Dan Harper

Global Advances in Research and Management of Aquatic Invasive Species

2016

ICAIS

FINAL PROGRAM

April 10 to 14, 2016
Fort Garry Hotel
Winnipeg, Manitoba, Canada

Hosted by

MEIA
Manitoba Environmental Industries Association

Conference Secretariat

Invasive Species Centre

Technical Program Committee Co-Chairs

Jeff Long
Manager, Fisheries Science and Fish Culture,
Manitoba Conservation and Water Stewardship

Becky Cudmore
Manager, Asian Carp Program and Aquatic Invasive Species Senior Advisor,
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University of Minnesota Sea Grant Program

Erika Jensen
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Frances Lucy
Institute of Technology, Sligo and Inland Fisheries Ireland

Sophie Monfette
Ontario Federation of Anglers and Hunters

Linda Nelson
U.S. Army Corps of Engineers

Stephen Phillips
Pacific States Marine Fisheries Commission

Kristine Pinkney
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Scott Poulton
Ontario Power Generation

Tanya Rushcall
Alberta Environment & Parks

Margo Shaw
Manitoba Environmental Industries Association

Deb Sparks
Invasive Species Centre

Gail Wallin
Invasive Species Council of British Columbia

Kate Wilson
Alberta Environment & Parks

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Conference at a Glance

Sunday, April 10, 2016

12:00 PM to 6:00 PM
Conference Registration
Speaker PowerPoint Submission

Monday, April 11, 2016

7:00 AM to 5:00 PM
Conference Registration
Speaker PowerPoint Submission

8:15 AM to 9:50 AM
Opening Plenary Session

9:50 AM to 10:20 AM
Networking Break

10:20 AM to 12:00 PM
Concurrent Sessions

12:00 PM to 1:30 PM
Luncheon (provided)

1:30 PM to 3:10 PM
Concurrent Sessions

3:10 PM to 3:40 PM
Networking Break

3:40 PM to 5:40 PM
Concurrent Sessions

5:30 PM to 7:00 PM
Poster Session and Exhibitor Reception

Tuesday, April 12, 2016

7:00 AM to 5:00 PM
Conference Registration
Speaker PowerPoint Submission

8:30 AM to 10:10 AM
Concurrent Sessions

10:10 AM to 10:40 AM
Networking Break

10:40 AM to 12:00 PM
Concurrent Sessions

12:00 PM to 1:30 PM
Luncheon (provided)

1:30 PM to 3:10 PM
Concurrent Sessions

3:10 PM to 3:40 PM
Networking Break

3:40 PM to 4:30 PM
Concurrent Sessions

Evening Free

Wednesday, April 13, 2016

7:00 AM to 5:00 PM
Conference Registration
Speaker PowerPoint Submission

8:30 AM to 9:50 AM
Plenary Session

9:50 AM to 10:20 AM
Networking Break

10:20 AM to 12:00 PM
Concurrent Sessions

12:00 PM to 1:30 PM
Luncheon (provided)

1:30 PM to 3:10 PM
Concurrent Sessions

3:10 PM to 3:40 PM
Networking Break

3:40 PM to 5:20 PM
Concurrent Sessions

Evening Free

Thursday, April 14, 2016

7:00 AM to 11:10 AM
Conference Registration
Speaker PowerPoint Submission

8:30 AM to 11:10 AM
Concurrent Sessions

11:10 AM
Conference Adjourns

Twitter Guidelines

The organizers of ICAIS encourage live tweeting throughout the conference under the hashtag **#ICAIS2016.** Some speakers and poster presenters may not want live tweeting about their presentations. The conference organizers thank all tweeters for respecting the wishes of those who do not want live tweeting.

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Session B: Asian Carps

Withdrawn

Session C: Ballast Water

Session B: Asian Carps

Withdrawn

Session C: Ballast Water

Session B: Asian Carps

Session C: Ballast Water

Wednesday, April 13, 2016

Plenary Session

Session A: Zebra & Quagga Mussel Control

Session B: Invasive Fishes: Behaviour & Dispersal

Session C: Aquatic Plants

Session A: Zebra & Quagga Mussel Control

Session B: Invasive Fishes: Diets & Impacts

Session C: Aquatic Plants

Session A: Zebra and Quagga Mussel Control

Session B: Invasive Fishes: Control & Genetics

Session C: EDNA and Genetics

Thursday, April 14, 2016

Session A: Dreissenid Mussel EDNA & Genetics

Session B: Global AIS Policy & Legislation Drivers

Monday, April 11, 2016

Plenary Session

8:15 AM

Welcoming Remarks

Tracey Cooke, Executive Director, Invasive Species Centre

Margo Shaw, Executive Director, Manitoba Environmental Industries Association

8:30 AM

Determining Priorities, Cutting Losses and Managing Conflicts Associated with Aquatic Invasions: A Southern African Perspective

Prof. Olaf Weyl, Principal Scientist, South African Institute for Aquatic Biodiversity

9:10 AM

Facing Aquatic Invasive Species in Europe: From Research to Policy

Elena Tricarico , Associate Professor, Department of Biology, University of Florence

9:50 AM

Networking Break

Session A

Species-Specific Outreach

10:20 AM

Working Together on Outreach for Asian Carps in the Canadian Waters of the Great Lakes

Erin L. Gertzen, Fisheries and Oceans Canada

10:40 AM

Asian Carps: Prevention and Early Warning for the Canadian Great Lakes

Alison Kirkpatrick, Ontario Federation of Anglers and Hunters

11:00 AM

Baseline Survey of Asian Carp and Invasive Species Knowledge in Ontario

Lauren Tonelli, Invasive Species Centre

11:20 AM

Great Lakes Sea Grant Network's Assessment of Asian Carp Research, Education and Outreach Efforts

Christopher J. Winslow, Ohio Sea Grant College Program

11:40 AM

Games as Instruments of Brazilian Elodea Prevention and Environmental Education in Cascade Reservoirs Region: Jaguara, Volta Grande and Igarapava, Located in Minas Gerais State/ Brazil

Andrea Carla Leite Chaves, PUC Minas - Pontifícia Universidade Católica de Minas Gerais

12:00 PM

Luncheon

Session B

Management and Control

10:20 AM

Achieving Control of Dreissenids throughout Entire Lakes: No, This Is Not Just Wishful Thinking

Daniel P. Molloy, University of Illinois at Champaign/ Urbana and Molloy & Associates, LLC

10:40 AM

Mesocosms to Advance Aquatic Invasive Species Control

Jim Davies, Alberta Innovates - Technology Futures

11:00 AM

Invasive Mussel Collaborative: Connecting People, Science and Management

Erika Jensen, Great Lakes Commission

11:20 AM

Great Lakes Restoration Initiative: Developing Tools and Approaches to Manage Aquatic Invasive Species

Bill Bolen, U.S. Environmental Protection Agency

11:40 AM

Comprehensive Response to the New Zealand Mudsnail Discovery in Wisconsin

Maureen Ferry, Wisconsin Department of Natural Resources

12:00 PM

Luncheon

Session C

Vectors and Pathways

10:20 AM

Past, Present, and Future Freshwater Fish Introductions in Canada

Nick Mandrak, University of Toronto Scarborough

10:40 AM

Vectors of Aquatic Introductions in the United States: Past and Present, Here and There

Mathew Neilson, U.S. Geological Survey

11:00 AM

A Risk Analysis of the Illegal Trade and Transportation Pathway for Regulated Aquatic Species in the Great Lakes

Michael Hoff, U.S. Fish & Wildlife Service

11:20 AM

Assessing the Potential Movement of Invasive Fishes through the Welland Canal

Jaewoo Kim, University of Toronto Scarborough

11:40 AM

First Record and Rapid Geographic Expansion of Spiny Water Flea (*Bythotrephes longimanus*) in Manitoba, Canada, 2009-2014

Wolfgang Jansen, North/South Consultants Inc.

12:00 PM

Luncheon

Monday, April 11, 2016

Session A

Audience-Driven Outreach

1:30 PM
Research and Implementation of Community Based Social Marketing: A Four Year Case Study in Aquatics
Gail Wallin, Invasive Species Council of British Columbia

1:50 PM
From Theory to Practice: Heuristics and Stop Aquatic Hitchhikers!
Douglas A. Jensen, University of Minnesota Sea Grant

2:10 PM
Using the Habitattitude Campaign to Address Pet Release Invasion Pathway in Wisconsin
Tim Campbell, University of Wisconsin Extension and University of Wisconsin Sea Grant

2:30 PM
What's in Your…? Water Garden and Aquarium AIS Outreach for the Great Lakes Region
Greg Hitzroth, Illinois-Indiana Sea Grant & Illinois Natural History Survey

2:50 PM
Don't Move a Mussel: Protecting British Columbia Waters from the Impacts of Invasive Species
Lisa K. Scott, Okanagan and Similkameen Invasive Species Society

3:10 PM
Break

Session B

Management and Control

1:30 PM
Integrated Approach to the Control of the Invasive Bullfrog *Lithobates catesbeianus*
Sarah Descamps, PXL Bio-Research – University Hasselt

1:50 PM
Restoration of a Large Freshwater Coastal Wetland, Delta Marsh, Manitoba, Canada: Exclusion of Common Carp (*Cyprinus carpio*)
Withdrawn
Dale Wrubleski, Ducks Unlimited Canada

2:10 PM
Getting Ahead of the Learning Curve – Ontario Lessons Learned in Response to Aquatic Invasive Species
Jeff Brinsmead, Ontario Ministry of Natural Resources and Forestry

2:30 PM
Looking into the Crystal Ball: Forecasting AIS Science and Information Needs in Ontario using the Delphi Method
Jeff Brinsmead, Ontario Ministry of Natural Resources and Forestry

2:50 PM
A Regional Approach to AIS Spread Prevention in the Adirondack Park: Boat Launch Stewards, Inspection, and Decontamination
Withdrawn
Margaret Modley, Lake Champlain Basin Program

3:10 PM
Break

Session C

Vectors and Pathways

1:30 PM
Chicago Area Waterway System as an Invasion Pathway for Crustaceans
Reuben Keller, Loyola University, Institute of Environmental Sustainability

1:50 PM
An Evaluation of Downstream Dispersal of Veliger Larvae as a Mechanism for Spread of Zebra Mussels between Inland Water Bodies in Minnesota
Michael McCartney, University of Minnesota

2:10 PM
Dreissenid Prevention Across the Pacific Northwest
Stephen Phillips, Pacific States Marine Fisheries Commission

2:30 PM
Developing a Vector Management Approach to Prevent Introduction and Spread of Marine Biofouling Invasive Species in Newfoundland
Kyle Matheson, Fisheries and Oceans Canada

2:50 PM
GLDIATR: Protecting the Great Lakes from the Internet Trade of AIS
Erika Jensen, Great Lakes Commission

3:10 PM
Break

Monday, April 11, 2016

Session A

Education and Extension

3:40 PM
Watercraft Inspection and Decontamination Programs in the Western United States
Dee Davis, Pacific States Marine Fisheries Commission

4:00 PM
Mussels and Mutts: The Alberta Conservation Canine Program
Cindy Sawchuk, Alberta Environment and Parks

4:20 PM
Operation Bait Bucket – Lake Simcoe Ontario. An Education and Awareness Program Focusing on Ice Anglers
Wil Wegman, Ontario Ministry of Natural Resources and Forestry

4:40 PM
A Student Research Project on Invasive Plants and Fishes: An EffectiveEducational Tool
Alain De Vocht, PXL Bio-Research – CMK, University Hasselt

5:00 PM
The Florida Invasive Plant Education Initiative
Katherine Walters, University of Florida, IFAS Center for Aquatic and Invasive Plants

5:20 PM
Invasive Species Education for Waterfowl Hunters
Brook Schryer, Ontario Federation of Anglers and Hunters

Session B

Species of Interest

3:40 PM
Is the Aquatic *Dikerogammarus villosus* a 'Killer Shrimp' in the Field? – A Case Study on One of the Most Invasive Species in Europe
Meike Koester, University of Koblenz-Landau

4:00 PM
The Trophic Function of *Dikerogammarus villosus* in the European Rivers Elbe and Rhine and its Impact on the Benthic Community
Claudia Hellman, University Koblenz-Landau

4:20 PM
The Devil is in the Detail; the Impact of Invasive Shrimps on the Reliability of Biotic Indices used to Assess Water Quality in Isle of Man Rivers
Calum MacNeil, Isle of Man Government

4:40 PM
Comparing the Predatory Impact of Invasive and Native Crabs on Prey Species: A Meta-analysis
Brett Howard, Simon Fraser University

5:00 PM
Individual Variation in Sea Lamprey Behaviour Has No Implications on Trapping Success
Emelia M. Myles-Gonzalez, University of Guelph, Department of Integrative Biology

Session C

Early Detection and Monitoring

3:40 PM
Caution! Some Dreissenid "Early Detection" Methods Are Actually "Early Deception" Methods
Daniel P. Molloy, University of Illinois at Champaign/ Urbana and Molloy & Associates, LLC

4:00 PM
Spread and Invasiveness of the Recently Introduced Chinese Mystery Snail (*Bellamya chinensis*) in Riverine Ecosystems in The Netherlands
Frank P.L. Collas, Radboud University Nijmegen

4:20 PM
Development of a Regional Surveillance Plan for the U.S. Waters of the Laurentian Great Lakes
W. Lindsay Chadderton, The Nature Conservancy

4:40 PM
Aquatic Invasive Species Monitoring in Wisconsin, USA
Maureen Ferry, Wisconsin Department of Natural Resources

5:00 PM
The Spread and Potential Impacts of Freshwater Invasive Island Apple Snails (*Pomacea maculata*) in Coastal South Carolina, USA
Amy Fowler, South Carolina Department of Natural Resources

Monday, April 11, 2016

Poster Session, 5:30 PM - 7:00 PM

Use of Unique Medium Pressure UV System Firstlight Energy's Shepaug Dam in Connecticut
Rebecca Allen, Firstlight Energy / GDF Suez

Human and Natural Correlates of Freshwater Invasive Species Occurrence
Amy J. Benson, U.S. Geological Survey

Habitat Invasibility and Thresholds of Impact of the Green Crab Invasion in the Southern Gulf of St. Lawrence, Canada
Renée Bernier, Fisheries and Oceans Canada

Engaging Youth on the Impacts and Implications of Aquatic Invasive Species on the Health of the Intertidal Zone in Placentia Bay Newfoundland
Kiley Best, Memorial University

Updating and Implementing the AIS Management Plan for Wisconsin
Tim Campbell, University of Wisconsin Extension

Games as Instruments of *Limnoperna fortunei* Prevention and Environmental Education in Cascade Reservoirs Region: Jaguara, Volta Grande and Igarapava, Located in Minas Gerais State/Brazil
Andrea Carla Leite Chaves, PUC Minas - Pontifica Unversidade Catolica de Minas Gerais

Movements and Habitat Use of the Invasive Species *Lithobates catesbeianus* in the Valley of the Grote Nete (Belgium)
Sarah Descamps, Hasselt University

Using Functional Responses in the Risk Assessment of Invasive Crayfish
Jaime Grimm, McGill University

A National Comprehensive Website on Aquatic Invaders in the Marketplace – TakeAIM.org
Danielle Hilbrich, University of Illinois

Determining the Effectiveness of the Clean Boats Crew: An Education and Outreach Program Aimed at Preventing the Spread of Aquatic Invasive Species in Lake County, Illinois
Danielle Hilbrich, University of Illinois

Eradication of Tench, an Invasive Fish New to Ontario
Maria Jawaid, Ontario Ministry of Natural Resources and Forestry

Designing and Testing New eDNA Markers for Aquatic Invasive Species
Richard F. Lance, U.S. Army Engineer Research & Development Center

Identifying Geographic Pathways of Zebra Mussel Spread: Minnesota as a Case Study
Sophie Mallez, University of Minnesota

Management of a Marine Invasive Species: Trapping as a Method to Control Abundances of European Green Crab (*Carcinus maenas*) in Newfoundland
Kyle Matheson, Fisheries and Oceans Canada

A Proposed Framework for Quantitative Risk Assessments of Aquatic Invasive Species in Ontario
Sarah Nienhuis, Ontario Ministry of Natural Resources and Forestry

Wisconsin's Framework for Aquatic Invasive Species Response
Amanda Perdzock, Wisconsin Department of Natural Resources

Review of Aquatic Invasive Species Disinfection Methods by Species
Amanda Perdzock, Wisconsin Department of Natural Resources

Innovative Solutions for Asian Carp Management
Kristine Pinkney, Invasive Species Centre

Impacts of New Zealand Mudsnails (*Potamopygrus antipodarum*) on Ecosystem Metabolism in a Cold Water Stream in Wisconsin, USA
Michael Shupryt, Wisconsin Department of Natural Resources

Spatial and Temporal Distribution of *Dreissena polymorpha* Larvae in a Warm Monomictic California Reservoir
Mark Sytsma, Portland State University

Asian Carp Canada Spot the Difference Poster Campaign
Lauren Tonelli, Invasive Species Centre

The Impact of Dissolved Oxygen and pH on Zebra Mussel Growth and Mortality in a California Reservoir
Tanya Veldhuizen, California Department of Water Resources

Intensive Sampling to Detect Newly Introduced Aquatic Non-indigenous Species
Sharon Yong, Great Lakes Institute for Environmental Research

Tuesday, April 12, 2016

Session A: Workshop

8:30 AM - 5:00 PM

Zebra and Quagga Mussels: Issues Relating to Infestations in Infrastructures and Open Waters

Part I (Morning): Biology, Environmental Requirements and Control of Dreissenid Mussels in Man-made Facilities

Renata Claudi, RNT Consulting Inc.

This workshop will cover:

- Life cycle of dreissenid mussels
- Environmental requirements for successful reproduction and survival
- Biofouling issues caused by dreissenid mussels in structures such as:
  - Intake systems
  - Cooling systems
  - Fire protection systems
  - HVAC Systems
  - Potable water treatment plants
- Fouling prevention vs. absolute barrier
- Available control strategies
  - Chemical
  - Non-chemical
- Regulatory environment

Part II (Afternoon): Infestations in Open Waters

Daniel P. Molloy, University of Illinois at Champaign/Urbana and Molloy & Associates, LLC

This workshop will address a wide range of topics relating to zebra and quagga mussel infestations in open waters (e.g., lakes and rivers), including:

- Key impacts of infestations in water bodies
- Key factors determining the risk of:
  - an initial introduction occurring in a water body
  - a population subsequently becoming established and reaching high densities
  - the spread of the infestation to another water body
- Prevention, detection, and rapid response programs and the key elements of designing and executing such programs
- Why an "early" detection program is no guarantee that an initial mussel introduction into a water body will be spotted "early" enough for eradication (i.e., 100% elimination) to be achieved
- Key factors contributing to the rare cases of successful eradication
- Why reductions in their densities throughout entire water bodies is rarely a feasible option
- Current control options for reducing infestations in relatively small, high-value areas, like beaches and docks
- Current and future research directions

Discussion will be encouraged both during the presentation and during a question and answer period.

Session A

Workshop

8:30 AM
Zebra and Quagga Mussels: Issues Relating to Infestations in Infrastructures and Open Waters Part I: Biology, Environmental Requirements and Control of Dreissenid Mussels in Man-Made Facilities
Renata Claudi, RNT Consulting Inc.

10:10 AM
Break

Session B

Asian Carps

8:30 AM
Status of Grass Carp in the Great Lakes
Duane C. Chapman, U.S. Geological Survey

8:50 AM
Evaluating the Potential for Overwinter Survival of Young-of-the-Year Gr... in the Great Lakes Basin
Withdrawn
Lisa A. Jones, Fisheries and Oceans Canada

9:10 AM
Corridor Between Lakes Huron and Superior: Potential Pathways for the Movement for Invasive Species
Lisa A. O'Connor, Fisheries and Oceans Canada

9:30 AM
Ontario Surveillance Efforts for Asian Carp in the Great Lakes
Chris Wilson, Ontario Ministry of Natural Resources and Forestry

9:50 AM
Assessing the Risks of Asian Carp Presence in the Chicago Area Waterway System: A Probabilistic Interpretation of eDNA Monitoring Results
Martin T. Schultz, U.S. Army Engineer Research & Development Center

10:10 AM
Break

Session C

Ballast Water

8:30 AM
Update on the Status of the IMO Ballast Water Convention
Christopher J. Wiley, Chair, IMO Ballast Water Group

8:50 AM
Fednav's Experience Installing Ballast Water Treatment Systems Onboard Great Lakes Carriers
Marc Gagnon, Fednav

9:10 AM
Using High Throughput Sequencing to Assess the Diversity of Propagule Pools Entering Ports via Ballast Water
John Darling, U.S. Environmental Protection Agency

9:30 AM
Evaluating Risks Associated with Ballast Water Release by Domestic Vessels Transiting to Canadian Arctic Waters
Kimberly Howland, Fisheries and Oceans Canada

9:50 AM
Survival of Hull Fouling Organisms During and After Voyages to the Canadian Arctic
Farrah Chan, Fisheries and Oceans Canada

10:10 AM
Break

Tuesday, April 12, 2016

Session A

Workshop

10:40 AM
Zebra and Quagga Mussels: Issues Relating to Infestations in Infrastructures and Open Waters Part I (continued): Biology, Environmental Requirements and Control of Dreissenid Mussels in Man-Made Facilities
Renata Claudi, RNT Consulting Inc.

12:00 PM
Luncheon

Session B

Asian Carps

10:40 AM
Comparing Analysis Techniques of High Throughput Sequencing for Asian Carp Monitoring
Withdrawn
Grace McCalla, U.S. Geological Survey

11:00 AM
Early Detection Surveillance Methods for Asian Carps in the Canadian Great Lakes
David Marson, Fisheries and Oceans Canada

11:20 AM
Lessons Learned from Grass Carp 2015 Responses in the Canadian Great Lakes
Becky Cudmore, Fisheries and Oceans Canada

11:40 AM
Law Enforcement Insights to Improve Coordinated and Effective Fishery Management
Jill Wingfield, Great Lakes Fishery Commission

12:00 PM
Luncheon

Session C

Ballast Water

10:40 AM
Testing Ballast Water Management Systems – Challenge Water Conditions During More than 100 Test Voyages
Withdrawn
Stephan Gollasch, Gollasch Consulting

11:00 AM
Ballast Water Sampling using Proportional Flow Control: Evaluating the Utility of External Ultrasonic Flow Meters in the Shipboard Environment
Cameron Moser, Excet Inc.

11:20 AM
Comparison of Sampling Devices and Analytic Methods for Ballast Water Compliance Testing
Johanna Bradie, Fisheries and Oceans Canada

11:40 AM
How Effective are Size-separation Techniques for Concentrating Live Organisms ≥10 µm and <50 µm?
Stephanie Robbins-Wamsley, Excet Inc.

12:00 PM
Luncheon

Tuesday, April 12, 2016

Session A

Workshop

1:30 PM
Zebra and Quagga Mussels: Issues Relating to Infestations in Infrastructures and Open Waters Part II: Infestations in Open Waters
Daniel P. Molloy, University of Illinois at Champaign/ Urbana and Molloy & Associates, LLC

3:10 PM
Break

3:40 PM
Workshop:
Zebra and Quagga Mussels: Issues Relating to Infestations in Infrastructures and Open Waters Part II (continued): Infestations in Open Waters
Daniel P. Molloy, University of Illinois at Champaign/ Urbana and Molloy & Associates, LLC

Session B

Asian Carps

1:30 PM
Development of a Novel Platform to Control Filter-feeding Aquatic Invasive Fishes
Jon J. Amberg, U.S. Geological Survey

1:50 PM
Examining Non-physical Barriers for Fish Movement: Electricity, Water Gun, Boomers, Bubble, Sound, Alarm Cue, and Light
Jaewoo Kim, University of Toronto Scarborough

2:10 PM
Bigheaded Carp Behavior and Bioacoustics
Brooke J. Vetter, University of Minnesota Duluth

2:30 PM
Evaluating Common Carp Responses to Behavioural Barriers in a Mesocosm
Paul Bzonek, University of Toronto Scarborough

2:50 PM
The Effect of Temperature on Acoustical Deterrence of Bighead (*Hypophthalmichthys nobilis*) and Silver Carp (*H. molitrix*)
Kelsie A. Murchy, University of Minnesota Duluth

3:10 PM
Break

3:40 PM
***In situ* Observations of Silver Carp Behavior when Presented with Broadband Sound**
Allen F. Mensinger, University of Minnesota Duluth

4:00 PM
Complex Sound as a Deterrent to Bigheaded Carp Passage
Marybeth Brey, U.S. Geological Survey

Session C

Ballast Water

1:30 PM
Evaluating Instruments Designed for Rapid, Shipboard Detection of Living Microorganisms in Ballast Water: An Initial Test of Compliance Tools
Matthew First, U.S. Naval Research Laboratory

1:50 PM
The Most Probable Number (MPN) Method to Quantify Organisms ≥10 µm and <50 µm: An Update
Lisa Drake, U.S. Naval Research Laboratory

2:10 PM
Uniform Response of Organisms in Different Phylogenetic Groups and Size Classes to Ballast Water Treatments
Scott Riley, Excet Inc.

2:30 PM
Efficacy of a NaOH-based Ballast Water Treatment System for Freshwater Ships: Mesocosm-scale Shipboard Trials
Adria Elskus, U.S. Geological Survey

2:50 PM
Evaluation of a Most Probable Number Method (MPN) Assay to Detect Living Organisms in Oligotrophic Water
Vanessa Molina, Excet Inc.

3:10 PM
Break

3:40 PM
Workshop: A Discussion of Ballast Water Sampling Approaches and Recommendations
Jonathan Grant, Battenkill Technologies, Inc.

4:00 PM
A Revised Assessment of the Most Probable Number (MPN) Method for Enumerating Viable Phytoplankton Cells in Ballast Water Discharge
John J. Cullen, Dalhouse University, Department of Oceanography

Wednesday, April 13, 2016

Plenary Session

8:30 AM
Understanding and Predicting the Impacts of Species Invasions: Old Challenges, New Approaches
Anthony Ricciardi, Redpath Museum, McGill University

9:10 AM
Metrics Based on Comparative Functional Responses and Abundance Reliably Predict Invasive Species Identities and Ecological Impacts
Jaimie T.A. Dick, Queen's University Belfast

9:50 AM
Networking Break

Session A

Zebra & Quagga Mussel Control

10:20 AM
The Use of Potassium Chloride to Control Zebra Mussels: Lake Winnipeg Harbours
Dan Butts, ASI Group

10:40 AM
Use of UV Radiation Technology to Prevent Settlement of Quagga Mussel Larvae
Jackson A. Gross, Smith-Root Inc.

11:00 AM
Evaluation of the Effects of Ultra-Violet Light Treatment on Quagga Mussel Settlement and Veligers at Davis Dam
Sherry Pucherelli, Bureau of Reclamation

11:20 AM
Use of Electrified Fields for Dreissenid Mussel Control
James A. Luoma, U.S. Geological Survey

11:40 AM
Microencapsulated BioBullets: An Effective Control Strategy for Invasive Mussels
David C. Aldridge, University of Cambridge

12:00 PM
Luncheon

Session B

Invasive Fishes: Behaviour & Dispersal

10:20 AM
Behaviour and Dispersal Potential in Invasive Fish Populations
Michael G. Fox, Trent University

10:40 AM
Behavioural Variation among Round Goby (*Neogobius melanostomus*) Individuals at Different Stages of the Invasion Process
Lida Nguyen-Dang, University of Windsor

11:00 AM
Life History Shifts in Invasive Populations: Nature or Nurture?
Anna C. Rooke, Trent University

11:20 AM
Changes in the Distribution and Abundance of Rainbow Smelt (*Osmerus mordax*) in the Nelson River, Manitoba, Canada, 1996-2015
Richard Remnant, North/South Consultants Inc.

12:00 PM
Luncheon

Session C

Aquatic Plants

10:20 AM
Sinking Water Soldier Permanently
Allison Kirkpatrick, Ontario Federation of Anglers and Hunters

10:40 AM
Great Lakes Phragmites Collaborative: A Collective Impact Approach to Non-Native Phragmites
Heather Braun, Great Lakes Commission

11:00 AM
Collective Development of a Science Agenda for Managing Non-native *Phragmites australis* through Microbial Intervention
Kurt Kowalski, U.S. Geological Survey

11:20 AM
Achieving a Consilience of Science and Stakeholders: An Integrated Aquatic Vegetation Management Plan for Lake Tahoe Keys Lagoons
Lars W.J. Anderson, WaterweedSolutions

11:40 AM
Benefits Derived in Louisiana from the Long Term Management and Control of Waterhyacinth (*Eichhornia crassipes*)
Alfred F. Cofrancesco, U.S. Army Engineer Research and Development Center

12:00 PM
Luncheon

Wednesday, April 13, 2016

Session A

Zebra & Quagga Mussel Control

1:30 PM
Optimization of Chlorination Strategies for Dreissenid Mussel Control
Scott Poulton, Ontario Power Generation

1:50 PM
Developing a Treatment Method to Protect Alberta's Irrigation Pipelines from Invasive Dreissenid Mussels
Nicole Seitz Vermeer, Alberta Agriculture and Forestry

2:10 PM
Mortality Responses of Quagga Mussels to KCl Solutions Prepared in Different Source Waters
Christine Moffitt, U.S. Geological Survey

2:30 PM
Control of Dreissenid Mussels with a More Rational Use of Copper
David Hammond, Earth Science Labs, Inc.

2:50 PM
Quest for Durable Foul-Release Coatings
Bobbi Jo Merten, Bureau of Reclamation

3:10 PM
Break

Session B

Invasive Fishes: Diets & Impacts

1:30 PM
Ecological Impact of Ponto-Caspian Invertebrates and Fish in a Shipping Canal Ecosystem
Alain De Vocht, University Hasselt

1:50 PM
No Significant Negative Impact on Native Fish Species during First Years of Colonization by Ponto-Caspian Gobies
Hugo Verreycken, Research Institute for Nature and Forest

2:10 PM
Evaluating and Predicting Impacts of Globally-invasive Freshwater Fishes using Multi-population Comparisons
Suncica Avlijas, McGill University, Redpath Museum

2:30 PM
Food Competition as a Mode of Impact in a Riverine Round Goby Invasion
Dustin Raab, McGill University

2:50 PM
Diet Spectrum and Preference of the Invasive Round Goby (*Neogobius melanostomus*) in Flanders
Hugo Verreycken, Research Institute for Nature and Forest

3:10 PM
Break

Session C

Aquatic Plants

1:30 PM
Growth of *Elodea canadensis* (in Swedish lakes): A Head Start for an Invasive Species in Strongly Seasonal Environment
Kristina Tattersdill, Swedish University of Agricultural Sciences

1:50 PM
Vegetative Reproductive Capacity of Crested Floatingheart (*Nymphoides cristata*)
Samantha N. Sardes, University of Florida, IFAS Center for Aquatic and Invasive Plants

2:10 PM
Ornamentals Behaving Badly
Nicole Kimmel, Alberta Agriculture and Forestry

2:30 PM
Mapping Watershed Degree of Invasion Across the Continental United States
Amy J. Davis, U.S. Environmental Protection Agency

3:10 PM
Break

Wednesday, April 13, 2016

Session A

Zebra and Quagga Mussel Control

3:40 PM
Evaluating Copper Ion Generator for Control of Quagga Mussels
Renata Claudi, RNT Consulting Inc.

4:00 PM
Invertebrate Community Response to Zequanox® in Aquatic Mesocosms
Michele Nicholson, Queen's University

4:20 PM
Developments in Bio-based Management of Juvenile and Larval Stage Zebra and Quagga Mussels in Industry and Natural Resource Management
Carolyn Link, Marrone Bio Innovations

4:40 PM
The Ins and Outs of Registering a New Product for the Control of Aquatic Invasive Species
John F. Fournier, Acadia Regulatory Consulting, LLC

5:00 PM
Use of a Differential Simple Stain to Confirm Mortality of Dreissenid Mussels in Field Research Experiments
Kelly Stockton-Fiti, KASF Consulting

Session B

Invasive Fishes: Control & Genetics

3:40 PM
Towards Selective Removal of Invasive Fishes and Passage of Native Fishes in Rivers
Rob McLaughlin, University of Guelph

4:00 PM
Ecology and Control of Invasive Northern Pike in the Columbia River, Canada
Brian Heise, Thompson Rivers University

4:20 PM
Invasion Genetics of the Eurasian Round Goby in North America: Patterns Across Time and Space
Matthew R. Snyder, University of Toledo

4:40 PM
Genetic Patterns of the Invasive Eurasian Ruffe Over Time and Space: Comparing Introductions in the Laurentian Great Lakes versus England
Devon J. Eddins, University of Toledo

Session C

EDNA and Genetics

3:40 PM
Decade of Gene Diversification of Viral Hemorrhagic Septicemia (VHS) Since its First Appearance in the Laurentian Great Lakes
Carol A. Stepien, University of Toledo

4:00 PM
Determining a Best-Case Effectiveness of a Molecular Method for the Detection of Aquatic Invasives
Ryan Scott, University of Windsor

4:20 PM
Early Detection Monitoring for Non-native Fishes and Invertebrates in the Lakes Erie and Michigan
Withdrawn
Stephen R. Hensler, U.S. Fish & Wildlife Service

4:40 PM
The Development and Validation of a LAMP Assay and Portable Instrument to Rapidly Detect Invasive Species in Transport as Bait
Christopher J. Merkes, U.S. Geological Survey

5:00 PM
How Much Can Environmental DNA (eDNA) Reflect a Local Macroinvertebrate Community in a Freshwater Flowing Habitat?
Rosetta C. Blackman, School of Biological, Biomedical & Environmental Sciences, University of Hull

Thursday, April 14, 2016

Session A

Dreissenid Mussel EDNA & Genetics

8:30 AM
Environmental DNA (eDNA) as a Monitoring Tool for Zebra Mussels in Lake Winnipeg
Timothy Gingera, University of Manitoba

8:50 AM
Development and Testing of High Throughput Sequencing Assays to Detect Aquatic Invasive Species from Environmental Samples
Katy Klymus, University of Toledo

9:10 AM
Varying Levels of Different Environment Factors Influence the Decay of Aquatic eDNA
Richard F. Lance, U.S. Army Engineer Research & Development Center

9:30 AM
Improvement of Methods for Detection of Dreissenid Mussels by Microscopy and Polymerase Chain Reaction
Jacque Keele, Bureau of Reclamation

9:50 AM
Where is the Body? Dreissenid Mussels, Raw Water Testing, and the Real Value of E-DNA
Denise Hosler, Bureau of Reclamation

Zebra and Quagga Mussel Population Studies

10:10 AM
Invasion History of *Dreissena polymorpha*, the Zebra Mussel in Lough Key, an Irish lake
Frances Lucy, Institute of Technology Sligo

10:30 AM
Zebra Mussel Habitat Selection, Growth and Mortality in Lakes of Northeastern Wisconsin and the Upper Michigan
Maureen Ferry, Wisconsin Department of Natural Resources

10:50 AM
The Status of Quagga Mussel Populations in Lake Michigan and Complementary Growth Experiments
Ashley Baldridge, National Oceanic and Atmospheric Administration (NOAA)

Session B

Global AIS Policy & Legislation Drivers

8:30 AM
The Roles and Responsibilities of Health Canada's Pest Management Regulatory Agency
Scott Couture, Health Canada

8:50 AM
Canada's Aquatic Invasive Species Regulations
Tracy Kerluke, Fisheries and Oceans Canada

9:10 AM
BC Invasive Mussel Prevention Program
Martina [illegible], Ministry of Environment
Withdrawn

9:30 AM
Redefining Norms: Alberta's Approach to Aquatic Invasive Species Prevention and Management
Kate Wilson, Alberta Environment & Parks

9:50 AM
Introduction to the New Ontario Invasive Species Act
Ala Boyd, Ontario Ministry of Natural Resources and Forestry

10:10 AM
Regional Collaboration to Protect the Great Lakes and St. Lawrence River
Mike Piskur, Conference of Great Lakes and St. Lawrence Governors and Premiers

10:30 AM
Considerations in Governance of Aquatic Invasive Species Management – Experience on the International Great Lakes
Gavin Christie, Great Lakes Fishery Commission

10:50 AM
Spatial Resolution Effects on Predicting the Distribution of Aquatic Invasive Species in Nearshore Marine Environments
Withdrawn
Ben J. Lowen, Fisheries and Oceans Canada

Session C

Prevention & Risk Assessment

8:30 AM
Inter-assessor Reliability of Risk Classifications for Invasiveness of Alien Species
Rob Leuven, Radboud University Nijmegen

8:50 AM
Comparing European Risk Assessments for Invasive Freshwater Invertebrates
Frances Lucy, Institute of Technology Sligo

9:10 AM
Prioritizing Species of Concern under Projected Climate Changes using a Temperature Matching Model
Tim Johnson, Ontario Ministry of Natural Resources and Forestry

9:30 AM
Invasion Risk of AIS Not in the Great Lakes Under Future Climate Scenarios
Phyllis Higman, Illinois Natural Features Inventory

9:50 AM
Conquering the Cold: Climate Suitability Predictions for the Asian Clam in Cold Temperate North America
Andrea Morden, McGill University

10:10 AM
A Risk Assessment of Golden Mussel (*Limnoperna fortunei*) for Ontario
Gerry Mackie, University of Guelph

10:30 AM
Canadian Columbia Basin: A Collaborative Approach to Aquatic Invasive Species Management
Jennifer Vogel, Central Kootenay Invasive Species Society

Determining Priorities, Cutting Losses and Managing Conflicts Associated with Aquatic Invasions: A Southern African Perspective

Olaf Weyl

South African Institute for Aquatic Biodiversity (SAIAB)

Southern Africa has a long history of introductions of aquatic plants, invertebrates and fish. Direct introductions, escapes from captivity, and unintentional spread have resulted in many introduced species becoming invasive. Impacts of invasions include the predation on and competition with native biota, habitat alterations, disease transfer and hybridization with native species. While the control of nuisance species (e.g., water hyacinth *Eichhornia crassipes*) typically enjoys public and institutional support, attempts to control species that have negative environmental but positive economic impacts often results in conflicts between stakeholders e.g., conservation authorities, fisheries departments, anglers and/or aquaculture practitioners. In a region where inland fisheries and aquaculture are investment areas for addressing economic development, food security and poverty eradication, resolving such conflicts is crucial if invasions are to be managed effectively. Here I provide an overview of the current knowledge on invasion pathways, status and ecological impact of three aquatic invasive conflict species in southern Africa: rainbow trout *Onchorhynchus mykiss*, Nile tilapia *Oreochromis niloticus* and redclaw crayfish *Cherax quadricarinatus*. These are discussed in the context of social and economic benefits derived from these species, the strong opposition to management interventions intended to contain invasions, and the process used in negotiating potential win-win solutions.

NOTES

Facing Aquatic Invasive Species in Europe: From Research to Policy

***Elena Tricarico**, Department of Biology, University of Florence*

In Europe, introductions of freshwater alien species have been continuously increasing throughout the years, especially in the last 60 years. This is likely explained by the marked increase in mobility and economic trade observed in Europe after World War II, as well as by the development of advanced aquaculture techniques and the opening of major inland waterway canals in Europe. According to recent studies, in Europe there are 756 alien freshwater species, introduced mainly through aquaculture, pet/aquarium trade and stocking activities. Germany, the United Kingdom and Italy are the main entry gateways of freshwater alien species. Considering the severe impacts exerted by many aquatic invaders, European policy makers drafted two important regulations to manage them: the first is a framework ruling aquaculture practices for alien and locally absent species (Council Regulation No 708/2007), the second is the Regulation 1143/2014 (entered into force on 1 January 2015) on invasive alien species. This last Regulation is based on the three-stage hierarchical approach recommended by the Convention on Biological Diversity (prevention, early detection and rapid eradication, and management) in order to protect native biodiversity and ecosystem services, and to minimize and mitigate the human health or economic impacts that these species can have. A list of invasive alien species of Union concern will be drawn up and managed with Member States, using risk assessments and scientific evidence of their impacts.

NOTES

Working Together on Outreach for Asian Carps in the Canadian Waters of the Great Lakes

Erin Gertzen[1], *Becky Cudmore*[1], *Sophie Monfette*[2], *Deborah Sparks*[3], *David Copplestone*[4]
[1]*Fisheries and Oceans Canada, Asian Carp Program*
[2]*Ontario Federation of Anglers and Hunters*
[3]*Invasive Species Centre*
[4]*Ontario Ministry of Natural Resources and Forestry*

The Canadian waters of the Great Lakes basin sustain 90% of Ontario's population and account for 40% of Canada's economic activity. The integrity and resource use of the Great Lakes have been impacted by a long history of aquatic invasive species (AIS), and the threat of future invasive species impacts remains. The lakes' vast size, multiple user groups, and many pathways make for a complicated landscape with respect to AIS management, specifically public outreach and education. To further complicate this issue, any one group with responsibility for prevention or management of AIS in the Canadian waters of the Great Lakes would have limited resources available to dedicate to the AIS threat. By teaming together, and combining efforts, Fisheries and Oceans Canada, Ontario Ministry of Natural Resources and Forestry, Ontario Federation of Anglers and Hunters, and the Invasive Species Centre have the ability to coordinate efforts to meet the significant challenges of protecting the large landscape of the Canadian waters of the Great Lakes. This presentation will discuss the issues faced in the basin, how a multi-group approach is conducted, and present examples of successes in meeting challenges.

NOTES

Asian Carps: Prevention and Early Warning for the Canadian Great Lakes

Alison Kirkpatrick[1], *Krystal Mitchell*[1], *Erin Gertzen*[2], *Becky Cudmore*[2]
[1]*Ontario Federation of Anglers and Hunters*
[2]*Fisheries and Ocean Canada*

With over 185 non-indigenous species established within the Great Lakes basin, there is a need to prevent the establishment of new invaders. Species like Asian Carps will cause massive ecological destruction, as well as strain the economy for millions of dollars if they are to successfully invade the Great Lakes. The Invading Species Awareness Program (ISAP), in partnership with Fisheries and Oceans Canada (DFO) has been delivering a comprehensive education and outreach campaign for Asian Carps in the Canadian Great Lakes regions, while promoting the public's role in maintaining healthy habitats and protecting them from invasive species. The campaign has two main goals: 1) prevent the introduction of Asian Carps to the Canadian Great Lakes, and promote and 2) encourage early detection/warning of Asian Carps in the Canadian Great Lakes. The ISAP utilizes networks of key outlets/audiences, such as bait shops, marinas, municipalities, conservation clubs, fishing charter operators, aquarium/pet stores, and tourist outfitters to distribute numerous educational materials promoting knowledge and awareness of Asian Carps, and encouraging potential sightings to be reported to the Invading Species Hotline, or via EDDMapS Ontario. Citizen engagement is an effective means of collecting invasive species sighting data within a wide geographic region, and public involvement in monitoring programs also increases understanding of the issue and encourages involvement in stewardship and prevention activities. Awareness and early detection is recognized as a critical pillar of Canada's strategy to prevent the spread and establishment of aquatic invasive species in our waters. By educating the public on the impacts of Asian Carps, how to identify these species, and how to report a possible sighting of this species, we can empower communities to help protect the Great Lakes watershed from an introduction of Asian Carps.

NOTES

Baseline Survey of Asian Carp and Invasive Species Knowledge in Ontario

***Lauren Tonelli**, Kristine Pinkney and Deb Sparks*

Invasive Species Centre

Investments are made in invasive species education, outreach, and communications with the expectation that public awareness of invasive species issues will result in positive, prevention-based behaviours.

Measurement of education and outreach activity outcomes over time enables the assessment of success, strategic decisions about future work, and demonstrates the value of future investments in awareness-raising and behaviour-modifying education and outreach activities.

In September 2015, the Invasive Species Centre conducted an Ontario-wide survey of 1,000 participants to gauge baseline levels of Asian carp and invasive species knowledge and viewpoints among the general public and analyzed the resulting data.

The findings of the baseline survey identify knowledge gaps, areas for future investments, and will inform the development of education and outreach materials and their avenues of dispersal, to best suit to the needs of targeted audiences.

NOTES

Great Lakes Sea Grant Network's Assessment of Asian Carp Research, Education and Outreach Efforts

Christopher J. Winslow
Ohio Sea Grant College Program

Sea Grant's university-based programs have strong research capabilities, local knowledge, and an on-the-ground outreach workforce. As a result, Sea Grant is recognized as an effective national network capable of rapidly identifying practical solutions to real problems facing our coastal resources. Through its research scientists, communications and education staff, and its extension efforts, Sea Grant generates, translates, and delivers cutting-edge, unbiased, science-based information to address complex issues. One such issue is the movement and potential impact of Asian Carp within the Great Lakes. The Great Lakes Sea Grant Network's research, education, and outreach reputation was enlisted by the Asian Carp Regional Coordinating Committee (ACRCC) to: (1) develop a bibliography of existing education and outreach materials on Asian Carp from the Mississippi and Great Lakes basins, (2) summarize existing education and outreach materials to identify the various messages being conveyed across the country, (3) survey state/federal agencies and academic researchers to identify and summarize current research on Asian Carp while identifying research gaps, (4) produce a regional educational power point presentation to convey research efforts, common outreach messages, and common misconceptions, (5) Identify a local network of speakers across the Great Lakes region to help the ACRCC carry current science-based information to the public and local interest groups, and (6) incorporate lessons learned from this effort into the current education and outreach (i.e., presentations, workshops, conferences) efforts that each program has developed related to invasive species. Ultimately, this project has increased the transfer of information to the public and important Great Lakes user groups about the danger posed by Asian Carp and what they can do to keep them from invading the system. Ultimately, we hope that our Great Lakes efforts have reduced the likelihood of a successful carp invasion.

NOTES

Games as Instruments of Brazilian Elodea Prevention and Environmental Education in Cascade Reservoirs Region: Jaguara, Volta Grande and Igarapava, Located in Minas Gerais State/Brazil

*Andrea Carla Leite Chaves[1], Claudia de Vilhena Schayer Sabino[1], **Maria Edith Rolla**[1], Ludmila Vieira Lage[1], Marcela David de Carvalho[2]*

[1]PUC Minas - Pontifícia Universidade Católica de Minas Gerais

[2]CEMIG - Centrais Energéticas de Minas Gerais

Brazilian elodea is a fast growing submerged aquatic plant that is having a significant impact on the shallow water habitat in the region of cascade reservoirs ecosystem. The aquatic weeds *Egeria densa* influences the local biological diversity and impacts on power generation, recreation and agriculture. It crowds out native plants, slows water flows, entraps sediments, obstructs waterways, impedes anadromous fish migration patterns and clogs agricultural and municipal water intakes. Aquatic plants surveying and consequently education for the public, means the prevention of problems to energy companies. This paper aims to present a didactic sequence on aquatic weeds. The production of this sequence is justified by research showing that teachers and students have difficulty understanding environmental issues, especially issues related to water. The purpose is to awaken curiosity and stimulate learning in order to contribute to effective teaching-learning process on infestation probability, focusing on prevention, environmental impacts and health risks. Educational products shown here include: game and manual targeted to teachers with information about Egeria densa and the game application in a classroom. These products offer current scientific information, using multimedia resources. The main aspects of the issue were addressed through short and callouts using simple language and easily understood associated with images that illustrate the information. It is expected that these materials can, through play activities, contribute to: (1) Bringing scientific knowledge from the classroom and the daily life of students and teachers; (2) Awakening the interest of students and teachers for water contamination problem; (3) contribute to the formation of individuals better informed and more active on environmental issues and related health; (4) Bring changes about the attitudes of teachers and students the subjects of research.

NOTES

Achieving Control of Dreissenids throughout Entire Lakes: No, this is Not Just Wishful Thinking

Daniel P. Molloy
University of Illinois at Champaign/Urbana and Molloy & Associates, LLC

There is a growing interest in the selective control of dreissenids in open waters. Unfortunately there is currently no dreissenid-specific control method capable of drastically reducing populations throughout an entire lake. Small high-value areas within infested lakes, however, like beaches and boat ramps will likely see increased use of the highly specific biological control agent Zequanox® or other control agents to reduce dreissenid densities. But these isolated control efforts while efficacious in these small areas will have little effect on the continual spread of dreissenids from lake to lake nor will they significantly reduce the ecological perturbations the multitude of remaining dreissenids are causing to the lake as a whole. In addition, no matter how dreissenid-specific a control agent is, typically cash-poor organizations such as lake associations would rarely have the financial resources needed to treat an entire water body even once (much less annually) with any currently available control agent. Ideally a control agent is needed that is applied just once, is self-spreading throughout an entire water body, and subsequently gives multi-year lake-wide control. There is only one type of control agent capable of that -- a live one, a biological control agent. This presentation will discuss the need for such an affordable, environmentally safe, and effective "entire-lake control agent" and will suggest that the only hope for such a powerful control agent is a hypervirulent, highly-specific, lethal parasite that when introduced into a lake would become established and self-spreading. This type of control method is not just wishful thinking, and examples will be presented that support the existence of such a parasite -- an organism with the potential to turn the tide against dreissenids across North America -- an organism with the potential to so reduce dreissenid populations that their ecological and economic impacts are likewise drastically reduced.

NOTES

Mesocosms to Advance Aquatic Invasive Species Control

Jim Davies[1], *Kate Wilson*[2]
[1]*Alberta Innovates – Technology Futures*
[2]*Alberta Environment & Parks*

Mesocosms, as replicated physical models of aquatic ecosystems, represent a unique tool for aquatic invasive species (AIS) research. These models permit ecosystem-level experimentation under realistic conditions while maintaining chemical and biological containment.

After constructing prototype mesocosms in 2013, Alberta Innovates – Technology Futures (AITF), in partnership with Alberta Environment & Parks, is moving forward with the design of a mesocosm facility intended to support the development and deployment of AIS control and detection technologies.

While there are a wide range of potential applications for the mesocosms, including a myriad of AIS and associated topics, the most imminent threat driving the current project is the lack of registered products for use in open water against dreissenid mussels. The Government of Alberta is interested in pursuing the registration of potassium chloride (potash) as a pest control product for use in lakes or reservoirs if dreissenid mussels are detected. The data gathered by this project will benefit many jurisdictions and partners, potentially facilitating open water registration across Canada and elsewhere.

Mesocosms constructed at AITF-Vegreville will experience climatic conditions consistent with most Prairie Province locales, producing regionally relevant results. Year-round experimentation will be supported by analytical chemistry, plant physiology, microbiology, and toxicology capabilities housed at the AITF-Vegreville research station. Construction and operation of the facility will be funded by a consortium, bringing together regional stakeholders to support projects whose deliverables are applicable across borders.

NOTES

Invasive Mussel Collaborative: Connecting People, Science and Management

Erika Jensen *and Sarah Cook*
Great Lakes Commission

Scientists have been searching since the early 1990s for effective methods to control invasive zebra and quagga mussels (*Dreissena polymorpha* and *D. rostriformis bugensis*, respectively) as a way to help mitigate their negative impacts. Recent advances in biocontrol technology represent an exciting potential technique to manage invasive mussels. These advances are also leading to new questions and opportunities for managers and scientists. 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. This presentation will focus on a new Invasive Mussel Collaborative that is providing a framework for communication and coordination to share information and lessons learned, guide supporting research, and inform management actions. This collaborative approach is helping to identify the needs and objectives of resource managers, prioritize the supporting science, recommend communication strategies, and ultimately align science and management goals into a common agenda.

NOTES

Great Lakes Restoration Initiative: Developing Tools and Approaches to Manage Aquatic Invasive Species

Bill Bolen[1], *Mark P. Gaikowski*[2], *Mike Weimer*[3]
[1]*U.S. Environmental Protection Agency*
[2]*U.S. Geological Survey – Upper Midwest Environmental Sciences Center*
[3]*U.S. Fish and Wildlife Service*

The Great Lakes Restoration Initiative (GLRI) has provided an unprecedented investment in ecosystem restoration of critical habitat of the Laurentian Great Lakes. Invasive species control is a critical component of GLRI, with resources supporting both on ground control of aquatic and terrestrial invaders as well as development of new tools and approaches to control them. With any large, multiagency effort, managing and allocating resources requires making multiple value judgements to identify how to efficiently allocate limited resources. For Asian carps (Bighead Carp, *Hypophthalmichthys nobilis* and Silver Carp, *H. molitrix*), the Asian Carp Regional Coordinating Committee (ACRCC) provides input and feedback to GLRI program coordinators on funding priorities. Development of new tools that can rapidly be implemented by management agencies is a priority of both the ACRCC and of GLRI. With resources provided by GLRI, the U.S. Geological Survey is leading research focused on supporting an integrated pest management approach to Asian carp control by enhancing detection, informing decisions on where/when to take management actions, and developing management tools. This multiagency, multidisciplinary effort is moving research into action through delivery of new tools. This presentation will discuss the lessons learned in the development of a large, multiagency research and management effort focused on aquatic invasive species control with special emphasis on Asian carps. The refinement of eDNA methods for surveillance and evaluation of carbon dioxide as a deterrent will be used as case studies in research management.

NOTES

Comprehensive Response to the New Zealand Mudsnail Discovery in Wisconsin

Maureen Ferry[1], *Laura MacFarland*[2], *Chris Merkes*[3], *Keith Turnquist*[4], *David Rowe*[1], *Jeanne Scherer*[1], *Michael Sorge*[1], *Jodi Lepsch*[1], *Amanda Perdzock*[1], *Tim Campbell*[5], *Blake Ruebush*[6], *and Jason Euchner*[7]

[1]*Wisconsin Department of Natural Resources*

[2]*River Alliance of Wisconsin*

[3]*United States Geological Survey – Upper Midwest Environmental Sciences Center*

[4]*University of Wisconsin-Stevens Point – Molecular Conservation Genetics Laboratory*

[5]*University of Wisconsin – Extension*

[6]*Illinois Department of Natural Resources*

[7]*Iowa Department of Natural Resources*

The first discovery of New Zealand mudsnails (*Potamopyrgus antipodarum*) (NZMS) in the inland Upper Midwest was in benthic samples collected from Black Earth Creek, Dane County in 2011. Following the discovery, a comprehensive monitoring and prevention project was implemented, including statewide winter benthic sampling and an environmental DNA (eDNA) pilot project. While benthic sampling did not detect new populations, the pilot project informed the design of a multistate eDNA surveillance effort where 45 sites in Iowa, Illinois, and Wisconsin were monitored for NZMS. The results provide a baseline understanding of NZMS distribution in the Midwest. Meanwhile, prevention efforts included partnering with the River Alliance of Wisconsin and Trout Unlimited to engage in wading angler outreach, constructing wader wash stations at known NZMS access points, and posting signs on other popular trout streams. This presentation will discuss monitoring and outreach efforts, their results, and future plans.

NOTES

Past, Present, and Future Freshwater Fish Introductions in Canada

Nicholas E. Mandrak
Department of Biological Sciences, University of Toronto Scarborough

Non-native freshwater fishes have had significant impacts on Canadian aquatic ecosystems since Common Carp was first introduced in the mid-1800s. Since then, the number of established species not-native to, and moved beyond their native range in, Canada has grown substantially. Dymond (1955) documented four native species and six range-extension species and Crossman (1984) documented 12 and 21 species, respectively. Currently, 19 non-native species and 24 range-extension species are established in Canada. Impacts of these species include habitat alteration, trophic disruption, genetic contamination, and disease. Pathways of introduction have changed over time from authorized stocking to ballast water to release from live fish trades. The ongoing importation of fishes, particularly through live trades, in conjunction with climate change will likely result in the ongoing establishment of new species. In addition, climate change may also facilitate the northward dispersal of new species into Canada from the United States.

NOTES

Vectors of Aquatic Introductions in the United States: Past and Present, Here and There

Matthew E. Neilson *and Pam L. Fuller*
U.S. Geological Survey, Wetlands and Aquatic Research Center

There are numerous vectors for introducing and spreading aquatic species, which may vary in importance and impact both spatially and temporally due to a variety of factors including species' biology, human behavior, demography, and geopolitical issues. Here we will examine spatial and temporal change in vectors of fish introductions in the United States, using data derived from the United States Geological Survey's Nonindigenous Aquatic Species Database. Most vectors show a general increase in number of species introduced over time. Sanctioned (i.e. stocking by natural resource agencies) and non-sanctioned (i.e., aquarium dumping) intentional releases were the most important vectors, with the relative importance of the vector switching ~1975 (more species introduced via stocking before 1975, and more released species afterwards). Vectors show differential geographic importance, with stocking more prevalent in western states and non-sanctioned release in the southeast. Governmental policy changes (e.g., ballast water regulations, natural resource management practices) and heightened awareness and education about impacts of introduced species may be driving a reduction in number of species introduced from 2001-present (relative to previous time period 1975-2000).

NOTES

A Risk Analysis of the Illegal Trade and Transportation Pathway for Regulated Aquatic Species in the Great Lakes

Michael Hoff[1], *Andrew Tucker*[2], *William Chadderton*[2]
[1]*U.S. Fish and Wildlife Service*
[2]*The Nature Conservancy*

The Great Lakes Water Quality Agreement (Agreement) is a commitment between the United States and Canada to restore and protect the waters of the Great Lakes. The Agreement was amended in 2012 to enhance water quality programs that ensure the "chemical, physical, and biological integrity" of the Great Lakes. New provisions of the Agreement address aquatic invasive species (AIS). One of the commitments, in the Agreement's AIS Annex, is to implement programs to prevent the introduction and spread of AIS by "conducting proactive, binationally-coordinated risk assessments on various pathways such as the trade and importation of live organisms." We conducted a risk analysis of the illegal trade and transportation pathway (Pathway) for regulated, aquatic species in Great Lakes jurisdictions. To assess risk of this Pathway, a questionnaire was developed, in cooperation with agency law enforcement personnel, to address nine major subpathways (Subpathways; internet, live bait, live food, aquaculture, private pond/lake stocking, water garden, aquarium/pet, cultural release, and biological supply). That questionnaire was completed, by law enforcement representatives from seven Great Lakes agencies, and resulting information was summarized to: 1) assess personnel expertise in relation to the Subpathways, and the management and investigation of those Subpathways; 2) assess risk of each Subpathway, and uncertainty in that assessed risk; and 3) evaluate and rank current risk management actions in his/her jurisdiction. Eight of the nine Subpathways assessed were considered "high" risk by at least one jurisdiction. Funding levels to manage the bait Subpathway was considered the single most important management action needed to reduce Pathway risk. We conclude that one or more Great Lakes law enforcement agencies are in need of additional funding, tools, training, and legal authorities for law enforcement program activities to better protect the Great Lakes from illegal trade and transport of regulated species.

NOTES

Assessing the Potential Movement of Invasive Fishes through the Welland Canal

Jaewoo Kim *and Nicholas E. Mandrak*
Department of Biological Sciences, University of Toronto Scarborough

The Welland Canal has been identified as a pathway for direct and indirect bi-directional movement of aquatic invasive species between Lake Ontario and the remaining Great Lakes. However, the direct movement of freshwater fishes including aquatic invasive species through the connecting channels such as Welland Canal are poorly understood. In 2012-2015, we conducted acoustic telemetry study to examine whether and how freshwater fishes move between Lake Ontario and Erie through the Welland Canal. In 2012-2015, we tracked the movement of 179 tagged fishes of 10 species using 34 acoustic receivers deployed throughout the canal. Over a million detections were collected. Our results indicate that the movement within the canal is dominant for most fishes. However, seven fishes (3.9%) such as Common Carp and Freshwater Drum were detected moving from the canal into lakes Ontario or Erie. In addition, five fishes were detected re-entering the canal the following year. We also used multi-state mark recapture models to describe the patterns of fish movement within the canal by estimating survival, detection, and transition probabilities. The results of 2012-2015 study have significant implications for developing effective management options to control the spread of aquatic invasive species.

NOTES

First Record and Rapid Geographic Expansion of Spiny Water Flea (*Bythotrephes longimanus*) in Manitoba, Canada, 2009-2014

Wolfgang Jansen[1], *Ginger Gill*[1], *Brenda Hann*[2]
[1]*North/South Consultants Inc.*
[2]*University of Manitoba*

The spiny water flea (SWF; *Bythotrephes longimanus*), an aquatic invasive zooplankton species native to Eurasia, was first recorded from Manitoba waters at the Pointe du Bois Generating Station on the Winnipeg River on 18 July, 2009. Based on drift net (43 x 85 cm opening; 950 µm mesh) samples in early June, SWF drift density upstream and downstream of the Pointe du Bois Station was highly variable with maximum densities of 23.3 individuals/m3 in 2010 (9 samples) and 9.4 individuals/m3 in 2012 (60 samples). The only consistent trend was that densities obtained from surface sets were approximately 50 times higher than those from bottom sets. In September of 2011, SWF was found in very small numbers in kick-net samples from nearshore areas of the Winnipeg River at Lac du Bonnet, approximately 50 river kilometers downstream of Pointe du Bois. In the fall of the same year, SWF were identified from the stomachs of eight Cisco (*Coregonus artedi*) collected from the south basin of Lake Winnipeg near the mouth of the Winnipeg River, indicating that the invader has become part of the local food web. Subsequent captures of relatively large numbers of SWF in kick-net samples from Mossy Bay at the north end of Lake Winnipeg in 2014 (when first sampled since 2010) and from Playgreen Lake approximately 7 km north of the Lake Winnipeg outlet in 2012 provide evidence for a rapid expansion of this species throughout Lake Winnipeg and further downstream in the Nelson River. The ecological implications of the SWF invasion for the Lake Winnipeg and Nelson River ecosystems will be discussed.

NOTES

Research and Implementation of Community Based Social Marketing: A Four Year Case Study in Aquatics

***Gail Wallin**, Jodi Roymn and Jennie McCaffrey*

You may know about invasive species, but what actions do you take to stop the spread? The shift from awareness to behaviour change is a challenge for organizations to achieve. If it is achieved, tracking behaviour change is also very difficult. Since 2011, the Invasive Species Council of BC (ISCBC) adopted community based social marketing (CBSM) to shift behaviours and create social norms on invasive species (i.e., recycling).

In 2012, ISCBC launched the largest field based CBSM research project on invasive species in Canada, and possibly North America, with 12 strategic test locations across BC. The project focused on prevention as the first step, rather than control after invasion. The target of the program (Clean Drain Dry) was to stop the spread of invasive species through behaviour change, and was tested in the field through a CBSM outreach model.

Clean Drain Dry (CDD) encourages you to clean, drain and dry all boats and equipment to help reduce the spread of invasive plants and organisms to BC waters. Boats and other watercraft act as vectors for invasive species entering key habitat within BC such as the province's lakes, streams and wetlands.

The ISCBC will present the CDD program as a case study of a successful behaviour change program. The results of evaluation from four years of research will be shared here, including plans for the spring of 2016. We will explore how CDD differs from a classic education/awareness program, and delve into the challenges associated with tracking and reporting positive behaviours related to aquatic invasive species.

NOTES

From Theory to Practice: Heuristics and Stop Aquatic Hitchhikers!

Douglas A. Jensen[1] *and Pat Conzemius*[2]
[1]*University of Minnesota Sea Grant Program*
[2]*Wildlife Forever*

Compared to two decades ago, aquatic invasive species (AIS) outreach has transformed. Advances in human dimensions research and use of technology provide new opportunities for strategic communication and outreach to prevent and slow the spread of AIS. Instead of information-based outcome programs, motivation-based programs are strategically planned, implemented, evaluated and adapted. Motivation-based programs integrate information about the basic beliefs, values, attitudes, norms, skills and actions of target audiences. Based in human dimension research, heuristics play an important role in problem solving, decision making, and planned actions. As mental shortcuts, they allow people to synthesize information efficiently. Shifting from previous behavior to desired behavior requires positioning of strategic and consistent messages. To this end, *Stop Aquatic Hitchhikers!* campaign partners generated 1.7 billion impressions since 2006.

The Great Lakes Sea Grant Network (GLSGN), led by Minnesota, engaged in the first comprehensive regional extension of the campaign using best media strategies and tools aimed at preventing the spread of AIS. Objectives of this study were to test if a heuristic approach using *Stop Aquatic Hitchhikers!* could influence awareness and behavior using strategic e-marketing. Wildlife Forever, the North American Media Group, and the GLSGN collaborated on five e-newsletters each with a specific message sent to 30,000 North American Fishing Club members from Minnesota to New York.

Partners then surveyed anglers to determine whether exposure to *Stop Aquatic Hitchhikers!* could change reported behavior. Results show rise in awareness and a change in behaviors with 97% reporting that they would take action to prevent AIS spread. Results will be compared to a conventional on-the-ground approach. Both studies demonstrate the effectiveness of the *Stop Aquatic Hitchhikers!* campaign at small and large regional scales. This presentation will discuss methodology and technology used to test how this heuristic approach worked.

Funding provided by the Great Lakes Restoration Initiative.

NOTES

Using the Habitattitude Campaign to Address Pet Release Invasion Pathway in Wisconsin

Tim Campbell[1], *Todd Verboomen*[2], *Jamie Kozloski*[3] , *Doug Jensen*[4]
[1]*University of Wisconsin Extension & UW Sea Grant*
[2]*East Central Wisconsin Regional Planning Commission*
[3]*Kingdom Animalia Exotic Animal Rescue*
[4]*University of Minnesota Sea Grant*

Organism in trade (OIT) invasion pathways are of increasing concern in Wisconsin. Discoveries of pacu, snakehead, and boa constrictors in Wisconsin waters are evidence that nonnative organisms are being released into the wild. Efforts to eradicate red swamp crayfish and yellow floating heart, both species thought to be introduced via OIT pathways, show that efforts to contain and eradicate these species can be costly. The Habitattitutde campaign is a community based social marketing approach to prevent pet releases and water garden escapes by promoting responsible consumer behavior and providing alternatives to pet release. However, through working with retailers it became clear that some of the options are not feasible in Wisconsin. To help make these alternatives possible, Wisconsin Sea Grant partnered with Kingdom Animalia Exotic Animal Rescue and East Central Wisconsin Regional Planning Commission to host pet surrender events. These efforts received media coverage while also accepting surrendered pets. We hope that these events can be a model that can be used to address these pathways in other communities.

Additionally, Wisconsin Sea Grant and Minnesota planned and hosted the Great Lakes Briefs on Invasive Organisms Traded in Commerce (GL BIOTIC) Symposium in Milwaukee. The GL BIOTIC Symposium drew speakers and attendees from across the Great Lakes region to hear experts speak on OIT invasion pathways and on topics related to OIT invasion pathway management. The information learned and the follow up products from the symposium will leave the Great Lakes region better prepared to address OIT issues in the future.

NOTES

What's in Your…? Water Garden and Aquarium AIS Outreach for the Great Lakes Region

Greg Hitzroth *and Patrice Charlebois*
Illinois-Indiana Sea Grant & Illinois Natural History Survey

AIS continue to be introduced into the Laurentian Great Lakes Region through intentional and accidental release of ornamentals used in the water garden and aquarium trades. To help curb these introductions, Illinois-Indiana Sea Grant (IISG), the Great Lakes Sea Grant Network and the Sea Grant Law Center created a suite of outreach tools for both the retail and hobbyist sectors of these trades. Development of these tools was directly informed by both social and biological sciences research with funding from the Great Lakes Restoration Initiative.

Researchers at North Carolina State University conducted a survey of water gardeners and aquarium hobbyists to understand their attitudes and behaviors related to purchasing and disposal practices. Researchers at the University of Notre Dame, Loyola University Chicago, and The Nature Conservancy conducted assessments of the potential invasiveness of species available in the trades. Results of the hobbyist survey were used to tailor the outreach products to best meet the existing needs of the audience. Results of the risk assessments provided information on which species to promote to and deter hobbyists from when making purchases.

The total suite of outreach tools available include: a national comprehensive OIT website (TakeAIM.org; IISG), non-technical summaries of Illinois and Michigan AIS laws (Sea Grant Law Center), a training video for water garden retailers (Wisconsin Sea Grant), a poster for water garden centers (IISG), plant and animal wallet cards for water gardeners (IISG and Pennsylvania Sea Grant, respectively), wallet cards for aquarium owners (IISG), and pencil and screen wipe message prompts featuring TakeAIM.org. When appropriate, these outreach tools also included abbreviated steps from the U.S. ANSTF guidelines for water gardens and classrooms. Likewise, when appropriate, these tools are being evaluated to determine their effectiveness in preventing the introduction and spread of AIS in the Great Lakes region via the OIT pathway.

NOTES

Don't Move a Mussel: Protecting British Columbia Waters from the Impacts of Invasive Species

Lisa K. Scott
Okanagan and Similkameen Invasive Species Society

The Okanagan Region and other areas of British Columbia (BC), Canada, are at extreme risk for invasion of several aquatic species, most notably Zebra and Quagga mussels; their arrival would be devastating to our drinking water systems, our environment and our economy. Preventing and detecting the invasion of aquatic invasive species (AIS) in uncolonized waters starts with education of the public. The importance of simply connecting with people to increase the understanding of AIS and the destruction they cause cannot be overstated. Social marketing research indicates that initiatives to promote change and new practices are often most effective when they involve direct contact with people.

Since 2012, the Okanagan and Similkameen Invasive Species Society (OASISS) has partnered with several organizations in south-central BC, to implement a valley-wide campaign educating water users about the impacts of invasive mussels. OASISS staff conduct one-on-one interactions at boat launches, campgrounds and community events, providing practical information and guidance to boaters and other water users. The society has connected with members from fish and game clubs, yacht clubs, marinas, lake associations and environmental groups, offering presentations to raise awareness about the impacts of invasive mussels and other AIS, and provide information on how to prevent their spread. Building capacity with these local aquatic stewards provides longevity to the program and significantly increases the number of citizens who understand how to effectively Clean-Drain-Dry boats and equipment. These stewards are well versed on what to look for and where to report any mussel detections.

Lessons have been learned during the four years of the program and new outreach tools are planned for 2016.

NOTES

Integrated Approach to the Control of the Invasive Bullfrog *Lithobates catesbeianus*

Sarah Descamps *and Alain De Vocht*
PXL Bio-Research – University Hasselt

The invasive species *Lithobates catesbeianus* causes a severe treat to native protected amphibians and ecosystems in Belgium. Populations reproduce, and are widespread in several parts of the country. In the valley of the Grote Nete approximately 400 ponds are infected over a distance of 30 km.

Direct eradication and population control of these invasive populations have high priority but are difficult due to the shyness of these animals and the inaccessibility of their habitats.

In an integrated approach, the symbiosis of catch-methods and SMRT (male-sterility) is considered as the best option for population control.

Different catch-methods, traps and baits were evaluated for adults and juveniles. Fykes and swimming traps were considered the best option.

Sterilization of the males can be obtained by chemical or physical procedures. First bisazir was injected into male adult bullfrogs at different concentrations. Comet assays on the sperm were carried out to evaluate the fragmentation of the DNA within the sperm. Bisazir injected bullfrogs showed severe DNA-fragmentation. Ecotoxicological tests were performed to evaluate the impact of bisazir on the aquatic ecosystem. The PNEC showed a concentration of <4µg/l. Toxicity assessments on *Schmidtea mediterranea* showed a blocking of the regeneration process.

To avoid toxic effects on the ecosystem chemical sterilization can be replaced by physical sterilization techniques. Therefore, fertilized eggs of the American bullfrog were manipulated which resulted in the production of aneu- and triploid individuals. After a behavioral survey these sterile triploid individuals can be applied in the sterile male release technique to control invasive populations or to stop further distribution through the commercial circuit.

These first findings can enhance the efficiency to control *Lithobates catesbeianus* in pond ecosystems outside their natural geographic range and therefore safeguard native biodiversity.

NOTES

Restoration of a Large Freshwater Coastal Wetland, Delta Marsh, Manitoba, Canada: Exclusion of Common Carp (*Cyprinus carpio*)

Dale A. Wrubleski
Ducks Unlimited Canada

Delta Marsh is a large, 18,500 ha, freshwater coastal wetland along the south shore of Lake Manitoba. Similar to other freshwater ecosystems, it is suffering from the effects of an artificially regulated water regime, eutrophication and invasive species, all of which have contributed to declining habitat for waterfowl and fish, and recreational opportunities. A multi-agency partnership has embarked on a ten-year restoration project to address the factors contributing to the deterioration of the marsh. Complicating the restoration effort is the fact that Delta Marsh cannot be managed in isolation. It is intimately connected to Lake Manitoba, with which it exchanges water, nutrients and fish. The first phase of the restoration project consists of management efforts to reduce the impacts of an invasive fish species, Common Carp (*Cyprinus carpio*), that overwinters in the lake and uses the marsh as spawning habitat. Experimental field studies have demonstrated that Common Carp are responsible for several changes observed in the marsh, including increased turbidity, phytoplankton blooms and loss of submersed vegetation. Common Carp exclusion structures have been constructed on the channels connecting the marsh to Lake Manitoba, and are designed and operated to reduce Carp access to the marsh while minimizing impacts on native fish species that also use the marsh for feeding, spawning, and rearing. A five-year monitoring program will adjust management efforts as required to favor marsh habitat improvements and balance needs of the native fish community. Initial monitoring results are showing improved water clarity and increased abundance of submersed vegetation.

NOTES

Getting Ahead of the Learning Curve – Ontario Lessons Learned in Response to Aquatic Invasive Species

Jeff K. Brinsmead *and Francine MacDonald*
Ontario Ministry of Natural Resources and Forestry

Once established, aquatic invasive species (AIS) are very difficult and expensive to eradicate or control, making prevention the most cost effective means of avoiding related impacts and expenses. However, when prevention measures fail, responding to AIS when populations are small and localized often presents the only opportunity to eliminate a species, and thus avoid the associated long-term impacts and management costs. In part due to its geography and socio-economic status, Ontario has a long history of non-native aquatic species introductions. Many of these species have thrived in the temperate climate of the Great Lakes basin and have become highly invasive. Over the past 25 years, Ontario has greatly increased the priority of and efforts related to AIS prevention and response. An overview of recent response projects in Ontario will be provided as well as some of the lessons learned during field response efforts. In January 2015, a workshop was held involving field and policy staff working for the Ontario Ministry of Natural Resources and Forestry who had previously participated in AIS response projects. Key challenges and recommendations from the workshop regarding the tools and resources needed to facilitate more effective responses in the province will be discussed. Documenting and discussing the results of response projects, what worked and what did not, and recommendations that can be applied to future projects will help improve the capacity for response in Ontario and elsewhere.

NOTES

Looking into the Crystal Ball: Forecasting AIS Science and Information Needs in Ontario using the Delphi Method

Jeff K. Brinsmead[1], *Rich Drouin*[1], *Randy French*[2], *Trevor Friesen*[1], *Tim Johnson*[1], *Bev Ritchie*[1], *Gord Rodgers*[2]
[1]*Ontario Ministry of Natural Resources and Forestry*
[2]*French Planning Services, Inc.*

While considerable aquatic invasive species (AIS) science and monitoring is being conducted in Ontario, there is also a perception that it does not provide all the information required by resource management and policy professionals to effectively prevent and manage AIS. Using the Delphi method, an iterative expert view based method of inquiry and feedback to establish consensus, we solicited input on AIS science and information needs from an expert panel comprised of resource management, policy and science staff across Ontario. While the focus was on the science and information priorities of Ontario Ministry of Natural Resources staff, experts from other agencies were included for a more complete picture of provincial information needs. The panel was asked to forecast priority AIS and pathways for future management, types of information needed to inform future management, and solutions to effectively communicate science and information to resource management and policy staff. By the end of the third survey, a convergence of the panelists' opinions had occurred and consensus on a short list of priorities was achieved for many of the survey questions. These results will help agency and academic researchers address the information needs of Ontario resource managers as well as those in other jurisdictions. Along with recent initiatives to develop additional policy and legislative tools, filling these science and information needs will assist resource managers in Ontario to better manage the threat posed by AIS. Observations on the use of and lessons learned about the Delphi method will be discussed.

NOTES

A Regional Approach to AIS Spread Prevention in the Adirondack Park Region: Boat Launch Stewards, Boat Inspection, and Decontamination

Meg Modley
Lake Champlain Basin Program

Aquatic invasive species spread prevention behavior at boat launches in the Adirondack region has been collected for over a decade by the Paul Smiths College Adirondack Watershed Institute, Lake George Association, Lake Champlain Basin Program and a number of lake associations. Data collected by these partner organizations has been coordinated and analyzed to reveal invasion spread hub lakes and a geographic picture of frequently visited lakes in the region. Partners worked with the Adirondack Park Invasive Plant Program to develop a white paper, *Boat Inspection and Decontamination for Aquatic Invasive Species Prevention Recommendations for the Adirondack Region*, that reviews invasive species spread prevention literature and makes recommendations for a strategic approach to prevent the landscape level spread of AIS. The paper includes recommendations to expand the boat launch steward program and identifies where to implement boat wash and decontamination stations. NY state Governor Cuomo approved $1M for the 2015 filed season to implement a boat steward, inspection, and decontamination program based on the boat launch steward data collected by partners. A review of the boat launch steward programs, data collected, recommendations of the white paper, and implementation of recommendations in the ADK Park will be reviewed.

NOTES

Chicago Area Waterway System as an Invasion Pathway for Crustaceans

***Reuben P. Keller**, Jonathon Brenner, Gabrielle Habeeb and Trent Henry*
Institute of Environmental Sustainability, Loyola University Chicago

The Chicago Area Waterway System (CAWS) is an artificial canal system that forms the strongest aquatic connection between the Laurentian Great Lakes and Mississippi River basins. Over recent decades it has become an important pathway for the spread of non-native species between these two ecologically and economically important freshwater ecosystems. Despite the history of recent invasions - including the high profile accorded to the potential invasion of the Great Lakes by Asian carp - very little sampling has been recently undertaken on non-fish taxa to determine what other non-native species are resident in the CAWS and may pose the risk of spreading through it. During summer 2015 we sampled crayfish and smaller crustaceans at sites throughout the CAWS and in Lake Michigan harbors. Invasive rusty crayfish (*Orconectes rusticus*) was the crayfish species most often encountered, and a large population of non-native red swamp crayfish (*Procambarus clarkii*) was found in the northern reaches of the CAWS. Native crayfish were only encountered in a single harbor (*O. virilis*) and in the relatively undisturbed North Branch of the Chicago River (*O. immunis* & *P. acutus*). Sampling for smaller crustaceans was focused on the potential spread of the scud (*Apocorophium lacustre*) from the Mississippi River basin into the Great Lakes. This species is classified as a species of concern by the U.S. Army Corps of Engineers, but has not previously been systematically searched for in the CAWS. Sample sorting is ongoing and will be complete for the presentation. Many non-native species are established in each of the Mississippi River and Great Lakes basins, and addressing the issues of spread among these basins will require a broad effort to identify species in the CAWS. This should include sampling across the CAWS, along with more sampling focused on non-fish taxa.

NOTES

An Evaluation of Downstream Dispersal of Veliger Larvae as a Mechanism for Spread of Zebra Mussels between Inland Water Bodies in Minnesota

Michael A. McCartney *and Sophie Mallez*
University of Minnesota, Minnesota Aquatic Invasive Species Research Center

Studies of zebra mussel spread to inland lakes suggest that downstream dispersal of veliger larvae is an important spread mechanism, particularly down short streams (< about 20 km). Direct studies of veliger transport (and settlement) down smaller streams, however, are available from only one lake/stream system in Michigan (MI). In Minnesota, downstream waters connected to zebra mussel-infested waters are designated as infested by the Department of Natural Resources (MnDNR) without physical evidence of mussels or larvae at the downstream site. However, this policy requires data on the effective dispersal distance of veliger larvae in these systems, which is lacking. In 4 systems with lakes interconnected by small streams or rivers, we estimated veliger concentrations and flux (numbers transported past a point, per day), as well as settlement of juvenile mussels on the streambed, at increasing distances downstream of infested lakes. Like the earlier study in MI, we found settlement to be highly localized—to areas < 1 km downstream of the infested lake in all 4 systems. We found larval supply to be high at sites < 2 km from source lakes. But whereas the MI study showed patterns that varied annually, we found that veliger concentrations and flux declined with distance downstream in all 4 streams and over 2 study years, while the steepness of decline varied among streams. Our results from settlement support earlier claims that populations of zebra mussels will not be self-sustaining in small streams and rivers. For short stream connections, larval "drift" is a potent mechanism of spread to downstream lakes, but it appears to decline (in some cases sharply) with distance—future studies to understand the cause(s) are needed. The average scale over which larval supply drops (10, 100, and 1000-fold) will be provided to aid MnDNR in their designation of infested waters.

NOTES

Dreissenid Prevention Across the Pacific Northwest

Stephen Phillips
Pacific States Marine Fisheries Commission

Zebra mussels and quagga mussels have been the most costly aquatic invaders in U.S. history as tens of millions of dollars are spent each year in managing zebra mussel infestations in the Great Lakes, Mississippi and now Colorado River drainages. The introduction of zebra and quagga mussels into the Columbia River Basin could not only threaten native species, but also industrial, agricultural, recreational, navigation, and subsistence use of the infested waters.

Dreissenid mussel transfer between basins in the western United States is most likely to occur through the movement of trailered watercraft. Government agencies and organizations in the western US have implemented watercraft interception programs designed to prevent contaminated watercraft from being launched in unaffected waterways. Hundreds of thousands of boats are inspected each year in the western US.

An overview will be provided an overview of western watercraft inspection programs, data on number of boats inspected and source waters of infested boats. This talk will also highlight challenges and successes of watercraft interception programs and future direction of interjurisdictional cooperative planning, prevention and management amongst state, federal and provincial agencies.

NOTES

Developing a Vector Management Approach to Prevent Introduction and Spread of Marine Biofouling Invasive Species in Newfoundland

Kyle Matheson[1], *Cynthia H McKenzie*[1], *Nicole Hynes*[2], *Bobbi Rees*[2], *Melissa Abbott*[1]
[1]*Fisheries and Oceans Canada*
[2]*Newfoundland Department of Fisheries and Aquaculture*

Since 2006, Fisheries and Oceans in Newfoundland and Labrador (NL) has led and collaborated with Provincial Department of Fisheries and Aquaculture and Memorial University on monitoring, surveys, risk assessments, and research on marine aquatic invasive species (AIS). These activities have guided various attempts to manage and control specific populations and such work led to the development of a rapid response framework. Its application has been used to control the spread of a recent invasion of the invasive tunicate, Ciona intestinalis. In NL, initial attention to early detection, monitoring, and rapid response has led to a shift from species specific to a more comprehensive vector best practices prevention and management approach. Fouling of submerged surfaces (e.g. docks and wharves) by invasive aquatic organisms can be a major vector for transfer of AIS locally and globally. In NL, such structures have played a prominent role in providing a foothold for populations of fouling invasive species (e.g. tunicates). While control efforts have included removal and cleaning of docks, stakeholder questions regarding further prevention have increased in urgency, particularly with regard to the new Aquatic Invasive Species Regulations within the Canadian *Fisheries Act*. Best management practices are being developed to provide local resource users, stakeholders, and management with the tools and information to actively prevent introduction and spread of marine AIS through vectors associated with human activities. Research is ongoing to provide advice to limit biofouling on docks and subsequent spread, including testing of antifouling coatings and use of sonication on docks and adjacent vessels. Furthermore, communication and education have proven to be one of the most critical components of this program and has been critical in leading to underwater surveys of floating structures before movement to or from infested areas. This presentation describes the current focus on vector management, marine best management practices and preliminary data and results on biofouling prevention.

NOTES

GLDIATR: Protecting the Great Lakes from the Internet Trade of AIS

Erika Jensen
Erika Jensen, Great Lakes Commission

There are many pathways by which AIS are introduced and spread in the Great Lakes-St. Lawrence River region. Some of these pathways are not well understood, and therefore, meaningful action is not being taken to address them. One such pathway is that of species being bought and sold over the Internet. Although widely recognized as a threat, the scope of this pathway was not well understood until recently. The Great Lakes Commission (GLC), with funding from the 2012 Great Lakes Restoration Initiative, completed development of the web-based software tool Great Lakes Detector of Invasive Aquatics in Trade (GLDIATR). GLDIATR collects, analyzes and allows users to access information about how many and what types of Great Lakes aquatic invasive species (AIS) are available for sale on the Internet. This information is being used by invasive species managers to inform and help target a variety of activities including outreach and education, risk assessment, monitoring and surveillance, and enforcement. In its first month of operation, GLDIATR identified more than 200 unique websites and sellers offering 58 different invasive species for sale. Species available for sale include seven of the 15 species labeled by the Great Lakes Governors and Premiers as the "least wanted" species, including several highly invasive plants – Brazilian elodea, parrot feather, water soldier, water chestnut and hydrilla. Outreach to identified sellers has also been undertaken to facilitate behavior change. The GLC's work to date has demonstrated that invasive species are in fact being sold over the Internet and that invasive species managers need tools to support their efforts to manage this pathway.

NOTES

Watercraft Inspection and Decontamination Programs in the Western United States

Deborah Davis[1], *Stephen Phillips*[2]
[1]*Training Contractor, Pacific States Marine Fisheries Commission*
[2]*Pacific States Marine Fisheries Commission,*

The expansion of inspection programs have increased the need to have trained inspection and decontamination program staff and managers regionally adopt protocols and standards to guide uniformity to the procedures and language amongst the state/agency programs.

To serve these needs the PSMFC began the Watercraft Inspection Training (WIT) program in 2006. To date, over 90 WIT Level I and Level II training classes have been conducted in 19 Western states (and British Columbia) involving thousands of participants. These individuals have trained thousand more in their respective programs.

The purpose is to teach natural resource personnel watercraft inspection and decontamination techniques and methods utilizing the "Uniform Minimum Protocols and Standards for Watercraft Interception Programs for Dreissenid Mussels in the Western United States."

The trainings utilized WIT training manuals that have been recently updated by the Western Regional Panel (WRP) on Aquatic Invasive Species' WIDT committee. These trainings have proven critical, as properly decontaminating fouled watercraft using current standards is an arduous task, and resource agencies need to be able to trust the decontaminations and inspections conducted by other jurisdictions.

NOTES

Mussels and Mutts: The Alberta Conservation Canine Program

Cindy Sawchuk
Alberta Environment and Parks

Alberta is one of the few jurisdictions left in North America that is free of invasive Dreissenid mussels. The cost of an infestation in the province is estimated to be $75 million annually. As such the provincial government is working to keep zebra and quagga mussels out through the development of an Aquatic Invasive Species prevention program. Given the importance of prevention, it is imperative to incorporate tools that are effective. In 2014, the Government of Alberta partnered with irrigation stakeholders and the Montana Department of Natural Resources to pilot the use of detection dogs to detect invasive mussels on watercraft. Working Dogs for Conservation was contracted to train their canines to inspect watercraft on either side of the border in a ten day pilot. As part of this pilot a comparison trial was also conducted to compare the accuracy and efficiency of trained watercraft inspectors versus trained canines. The overwhelming success of this pilot led to the creation of the Alberta Conservation Canine Program – an innovative approach to prevent an introduction of invasive mussels. Alberta is the first jurisdiction in Canada to employ full time detection dogs at mandatory watercraft inspection stations throughout the province.

NOTES

Operation Bait Bucket – Lake Simcoe Ontario. An Education and Awareness Program Focusing on Ice Anglers

Wil Wegman
Resource Management Technician, Ontario Ministry of Natural Resources and Forestry, Aurora District

Lake Simcoe is located just north of Toronto and is the most intensively fished inland lake in Ontario for recreational purposes. Ice fishing there is incredibly popular and more people fish the lake during the winter than the rest of the year combined. The Lake Simcoe Protection Act (2008) and the Lake Simcoe Protection Plan (2009), identified Aquatic Invasive Species as a major threat to the lake's ecosystem and directed efforts be made to slow the spread of invasives. Angler movement of baitfish and dumping of leftover bait has been identified as two major pathways that could introduce unwanted invasives.

To address the threat of new aquatic invasives entering the lake, as well as to minimize their spread from Lake Simcoe to other waterbodies, MNRF Aurora District and the Ontario Federation of Anglers and Hunters have partnered on several initiatives – including billboards, lakeside signage, brochures,and angler outreach through the Operation Boat Clean and Operation Bait Bucket (OBB) program.

OBB is a joint education and awareness program that started in 2006. Roving crews travel the lake on snowmobiles, talking to ice anglers about invasive species and diseases like Viral Haemorrhagic Septicaemia (VHS). Their key messages " Don't dump leftover baitfish down the hole! Buy and use baitfish locally," have been well received by ice anglers. Since 2006, OBB staff have spoken to over 5,100 ice anglers on Lake Simcoe.

Raising public awareness about preventing invasive species introductions is a key mandate to the effective management of invasive species in Ontario. Interacting with ice anglers one-on one through programs like OBB can help change angler behavior and protect this important lake and its fishery for future generations.

NOTES

A Student Research Project on Invasive Plants and Fishes: An Effective Educational Tool

Alain De Vocht *and Sarah Descamps*
PXL Bio-Research – CMK, University Hasselt

Bachelor students studying 'Nature and Forest management' carried out an educational student research project on invasive alien species (IAS) in a limestone quarry in Belgium. The aim of the educational project was to enhance student's knowledge of the vulnerability of novel ecosystems for both terrestrial as aquatic invasive species and to increase student's insight in the important potentials for habitat restoration for endangered species in quarries.

This project will investigate the invasive species butterfly bush (*Buddleja davidii*), a major problem in quarries and source for dispersion in adjacent habitats or ecosystems, such as river gravel banks. The project investigated the distribution and habitat specificity in the quarry of Loën. A soil sampling scheme and mapping of Butterfly bush was carried out. Soil analyses were carried out and methods to eliminate and control the species were studied and presented by the students.

Secondly the biodiversity of fishes in the central pond in the quarry was studied. The fish fauna was investigated by electrofishing. The presence of carp (*Cyprinus carpio*) has a negative effect on the reproductive success of endangered amphibians as natherjack toad in the quarry. Based on the inventory, adequate measures to enhance the aquatic fish or amphibian biodiversity and the control of invasive alien fish species were formulated.

A survey of the students before and after the project showed an effect change in insight in both opportunities for biodiversity and threats by IAS. The project succeeded to widen the student's opinion and opened their minds regarding the potentials and threats in novel ecosystems and their knowledge in management of invasive alien species. The project was rewarded the first Benelux Quarry Life Award.

NOTES

The Florida Invasive Plant Education Initiative

Katherine Walters, William T. Haller and ***Lyn A. Gettys***
University of Florida, IFAS Center for Aquatic and Invasive Plants

The Florida Invasive Plant Education Initiative began in 2004 as part of a long-term education and outreach partnership between the University of Florida/IFAS Center for Aquatic and Invasive Plants and the Florida Fish and Wildlife Conservation Commission, Invasive Plant Management Section. Over the last ten years, we have developed an extensive program to get invasive species issues taught in the classroom - with a combination of training, lesson plans aligned to educational standards, and activities that truly engage students. Our continuing partnership with the Florida Fish and Wildlife Conservation Commission (FWC) and organizations such as the Florida Aquatic Plant Management Society (FAPMS), the Aquatic Plant Management Society (APMS), and the Aquatic Ecosystem Restoration Foundation (AERF), allow us to offer these materials and workshops at no cost to Florida educators. Over 300 teachers have attended our workshops who, in turn, have taught more than 70,000 Florida students over the last 10 years. We provide complete curriculum modules, an annual professional development workshop for educators (PLANT CAMP), online resources, in-class presentations, and educational materials and games. Regular communication and collaboration with teachers ensures our materials remain relevant and useful.

The two main resources the Education Initiative offers are *Plant Camp – For Teachers Only!* and *Lakeville – A Natural Resource Management Activity*. Plant Camp is an annual 5-day workshop that provides Florida educators with the unique opportunity to learn first-hand about natural resource management issues in Florida. Faculty from the University of Florida, state park biologists, administrators from FWC's Invasive Plant Management Section, and plant managers from the private sector provide content knowledge and laboratory and field experience in aquatic and upland plant biology and ecology. Data from pre- and post-tests from last year's workshop show an average gain of 14%, with individual questions ranging from 0% to 114% gain. We also saw a change in attitude regarding invasive plant management. Participants ranked whether they opposed or favored chemical, biological, mechanical, and physical methods of plant management pre- and post-workshop. Pre-workshop showed 6 "strongly opposing" and 17 "opposing" views in total; post-workshop showed only 1 "opposing" (physical) view.

Lakeville - A Natural Resource Management Activity is a curriculum unit educators learn to implement during Plant Camp. Lakeville provides a basic understanding of the role native, non-native, and invasive species play in ecosystems and the social significance of these ecosystems. Students are challenged to make management decisions based on their new understanding, taking the perspectives of various stakeholders in their community into account as they attempt to address the problem of invasive species. Students then assess what effect their decisions will have on the ecosystem, solidifying their understanding and bringing up new ideas and questions to explore.

Since 2012, the Education Initiative has partnered with APMS to develop Lakeville Units for other states: North and South Carolina and Alabama. Educators from each of these states attended the Florida Plant Camp to get background information and training to bring Lakeville and other invasive species activities back to their classrooms. In 2015 the first Alabama Plant Camp was held. Plans are in place for the first South Carolina Plant Camp to happen in 2016. The Florida Invasive Plant Education Initiative continues to look for partners to utilize this successful program to create invasive species lessons for classrooms and educators across North America.

NOTES

Invasive Species Education for Waterfowl Hunters

Brook Schryer
Ontario Federation of Anglers and Hunters

Hunting is part of our cultural heritage. To preserve this heritage, it is important to preserve the ecosystems in which we hunt. Invasive species are one of the greatest threats to the biodiversity of Ontario's waters and woodlands, and it is important for waterfowl hunters to be educated on invasive species and their effects of waterfowl hunting. The goal of this project was to educate waterfowl hunters on the negative impacts associated with invasive species (e.g. social, economic, and ecological), and how hunters can help prevent their introduction and spread. The key messages shared with waterfowl hunters were: 1) hunters can inadvertently spread invasive species by way of boats, motors, trailers, decoys, or hunting dogs, 2) hunters can unintentionally build hunting blinds with invasive plants, and 3) the spread of invasive species can affect the amount of waterfowl in a particular area. Resources were developed to communicate these messages, as well as share information on how waterfowl hunters can address these issues in order to prevent the introduction and spread of invasive species, and preserve waterfowl hunting opportunities in Ontario. To achieve the overall goal of increasing knowledge among waterfowl hunters in Ontario, the Invading Species Awareness Program (ISAP) developed a multi-media targeted outreach campaign for waterfowl hunters. Highlights of the campaign include: the development of an educational brochure, a radio public service announcement (PSA), a video PSA, a self-directed online and DVD format workshop, in person workshops, establishing partnerships with more than 30 retail outlets across Ontario, weekend outreach at major retail outlets (i.e., Bass Pro Shops and Cabela's), and radio/newspaper interviews. This campaign has, and continues to reach thousands of waterfowl hunters across Ontario.

NOTES

Is the aquatic *Dikerogammarus villosus* a 'Killer Shrimp' in the Field? – A Case Study on One of the Most Invasive Species in Europe

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One of the most important invasive species in Central-Europe is the ponto-caspian amphipod *Dikerogammarus villosus*. The species succeeded in colonising most European inland waterways within two decades and has great potential to reach overseas ecosystems like the Great Lakes. Following the establishment of *D. villosus* in invaded systems, decreasing densities of many other macroinvertebrate taxa in invaded habitats were recorded. Previous laboratory studies have revealed a strong potential predatory impact of *D. villosus* on other macroinvertebrate species, including other amphipods.

This predatory behaviour is often assumed to be the key driver of the observed species displacement. Therefore, in recent years *D. villosus* is often called 'killer shrimp'. However, little is known about the importance of the predatory strength of *D. villosus* in the field. Since natural conditions are much more complex than simulated in laboratory experiments, we hypothesised that this factor is of minor importance in the field independent from the colonised habitat. To test this, we used bulk stable isotope analyses of $\delta^{13}C$ and $\delta^{15}N$ of *D. villosus* and potential food resources to determine the tropic niche of *D. villosus* in different habitats of the River Rhine system. Our results show that the feeding strategy of *D. villosus* is on average similar to that of primary consumers, like *Potamopyrgus antipodarum*, *Jaera* sp. and *Corbicula fluminea*, co-occurring in the different habitats studied. However, the isotopic signature of *D. villosus* shows high intraspecific variability, which can even exceed one trophic level. Furthermore, SIBER analyses revealed a similar trophic position for *D. villosus* and the coexisting amphipod species and showed a strong overlap of their trophic niches. This study clearly indicates a minor importance of the predatory behaviour of *D. villosus* in the field, but also gives hints for a strong differentiation within one population of the invasive amphipod.

NOTES

The Trophic Function of *Dikerogammarus villosus* in the European Rivers Elbe and Rhine and its Impact on the Benthic community

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The amphipod *Dikerogammarus villosus* has invaded European rivers very successfully and is expected to continue its invasion over the sea. Its occurrence is often assumed to be associated with a change in the aquatic community and a loss of biodiversity. The main reason for these consequences is seen in the ability of *D. villosus* to prey strongly on other invertebrates, which was observed in laboratory experiments. However, its trophic role in natural food webs is not well known and first studies show contrasting results. We therefore investigated trophic position and diet use of *D. villosus* in benthic communities of two large European rivers (rivers Elbe and Rhine, Germany) by analysing stable isotope signatures. *D. villosus* had a relatively low trophic position in both food webs, indicating its function as primary consumer or omnivore. The trophic function differed between the two rivers and depended on the benthic community composition of the specific ecosystem. An isotope mixing model indicated the intense use of leaves and only minor relevance of other invertebrates as resources for *D. villosus*. To analyze the impact of *D. villosus* on the benthic river community, we used several mesocosms experiments with different densities of *D. villosus* in the rivers Elbe and Rhine and long-term monitoring data of benthic river communities from 5 to ten years before the invasion until now. These data did not support the assumption of a general negative impact of the invader on the community. We observed direct effects on other benthic species, which however differed between the two rivers and therefore seem to be ecosystem-specific.

NOTES

The Devil is in the Detail; the Impact of Invasive Shrimps on the Reliability of Biotic Indices Used to Assess Water Quality in Isle of Man Rivers

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Gammarus pulex and *Crangonyx pseudogracilis* are freshwater amphipod 'shrimp' invaders which have become firmly established in river systems in a small British Island, the Isle of Man, over the past several decades. The European *G. pulex* and the North American *C. pseudogracilis*, the former deliberately introduced, the latter by accident, feature regularly in macroinvertebrate assemblages used in biotic indices for ecological assessment of river water quality and for enforcement purposes following pollution events. Occasionally, one or both invaders may be found co-occurring with the native Isle of Man shrimp *Gammarus duebeni celticus* but often the only 'shrimp' present in a sample used for water quality assessment /enforcement purposes may be an invader. I show by field survey and field experiment that both invaders have the ability to undermine the reliability of established biotic indices, whether it be by being more predatory/competitive than the native or more tolerant of poor organic chemical water quality. I provide examples from both the Isle of Man Government's routine water quality monitoring programme and from past enforcement cases relying on biotic indices to reflect pollution impacts, to highlight the increasing problems invaders pose to effectively and reliably reflect changing water quality. Relatively simple ways to account for the presence and impacts of such invaders in macroinvertebrate samples used in ecological assessment / enforcement cases are discussed.

NOTES

Comparing the Predatory Impact of Invasive and Native Crabs on Prey Species: A Meta-analysis

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As invasive marine crab species (including the European green crab, Chinese mitten crab, and Japanese shore crabs) continue to spread worldwide there is growing concern about the potential impacts on native species and habitats. This has generated a large body of experimental research attempting to quantify the effects of these invasive aquatic species. However, the utility of this research in generating broader conclusions about marine crab invasions is limited, as individual studies are restricted by region, experimental design, and species studied. Results from study to study often appear contradictory and this variability makes it difficult apply them individually to the development of invasive species management policies. Therefore, we conducted a meta-analysis to compare the impact of native and invasive marine crabs worldwide on prey survival rates using published experiments where crab presence was manipulated. In our dataset we included a variety of potential factors that could influence effect size, including: prey type, direct versus indirect effects, experimental design, and crab species. Overall our results show that native crabs reduce prey survival slightly more than invasive crabs. However, invasive crabs do have a greater negative effect than native crabs on the survival of certain types of prey, including bivalves and marine worms. The most detrimental invasive crab species, determined by effect size, were the Atlantic mud crab (*Dyspanopeus sayi*), the Japanese shore crab (*Hemigrapsus sanguineus*), and the European green crab (*Carcinus maenas*). The potential impact of these invasive marine crabs is greatest in the Mediterranean and on the east coast of North America. Our results support the current perception that dietary and physiological versatility combined with high consumption rates allow invasive crab predators to exploit potentially underutilized prey types and habitats, allowing them to become successful and detrimental aquatic invaders.

NOTES

Individual Variation in Sea Lamprey Behaviour Has No Implications on Trapping Success

Emelia M. Myles-Gonzalez *and Rob L. McLaughlin*
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Trapping is used to control a variety of invasive species, including the Sea Lamprey (*Petromyzon marinus*) in the Upper Great Lakes. Trapping success for Sea Lamprey is currently lower than desired for control purposes. One hypothesis to explain low trapping success is that individual differences in behaviour influence their susceptibility to trapping. We tested whether adult migrating Sea Lamprey 1) differ consistently in their behaviour, and 2) if these behaviours differed between lamprey sampled from traps and lamprey collected at large from the spawning river downstream of traps. Using lab-based behavioural assays in 2014, we tested for consistent individual differences in latency to exit a refuge (a measure of bold/shy), proportion of time spent moving (a measure of activity) and response to a conspecific alarm cue (a measure of risk taking). We then tested if individuals collected from traps were bolder, more active and more likely to take risks than individuals sampled from the river downstream of the traps. Lamprey differed consistently in each of the behaviours, independent of location, sex and body size, supporting prediction 1, but did not differ based on capture method, failing to support prediction 2. Our findings suggest that the behavioural differences identified in our study do not account for the low trapping success observed for Sea Lamprey, but further research into other behavioural attributes of lamprey approaching and entering traps is needed to assess the strength of this hypothesis.

NOTES

Caution! Some Dreissenid "Early Detection" Methods are Actually "Early Deception" Methods

Daniel P. Molloy, *University of Illinois at Champaign/Urbana and Molloy & Associates, LLC*

Typically "early detection" dreissenid programs use plankton net tows and artificial substrate samplers with the expectation that once a dreissenid is observed using these devices, there is a reasonable chance of successfully containing and then eradicating the population. Unfortunately, such "early detection" programs are more like "early deception" programs since in the vast majority of cases they initially detect their first dreissenid long after there is a reasonable chance of successfully carrying out an eradication attempt. The following two questions help to explain this deception:

1) *What percent of the water in an entire water body is actually sampled when towing a plankton net? Answer: A miniscule percent*. The chance of the net collecting the veligers that were actually introduced is near zero. Catch a veliger in a net, and it almost invariably means that it and thousands of others that were born in that water body (or an interconnected water body) have been floating far and wide for weeks. The opportunity for containment and eradication is, therefore, near zero as the dreissenids are already too widely dispersed.

2) *What percent of all hard surface areas within the water body do the surfaces of artificial substrate samplers represent? Answer: A minuscule percent*. The dreissenids that are initially introduced into a water body eventually will settle and attach. The likelihood, however, that an initial colonizing mussel will attach to the surface of an artificial sampler is, thus, miniscule compared to its attaching to another surface. Typically by the time a dreissenid is first noted on an artificial substrate sampler, a reproducing population is already widely distributed, with the mussel on the sampler being one of its progeny.

Detection programs using plankton nets and substrate samplers, however, are still valuable and should not be eliminated, as they can serve as the first indication that a water body has become infested and subsequently be used to monitor the extent of the infestation over time. We must, however, just not be deceived into expecting that they will provide "early" enough detection to allow population containment – the key factor in a successful eradication attempt.

NOTES

Spread and Invasiveness of the Recently Introduced Chinese Mystery Snail (*Bellamya chinensis*) in Riverine Ecosystems in The Netherlands

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The non-native Chinese mystery snail (*Bellamya chinensis*) was observed in three freshwater bodies in the Netherlands in 2010. These records were the first in Europe. The species is now known from six sites, including riverine ecosystems. At two of these locations adults and juveniles were recorded during several years, thus viable populations have been established in the Netherlands. Insight in the ecological, socio-economic and public health effects of the species in Europe is urgent due to its continuous spread and potential invasiveness. A field survey carried out to determine dispersal rate, habitat and population characteristics of this species in floodplains along the river Meuse demonstrated that the natural dispersal rate was less than 100 m per year and population densities were < 0.5 individuals per m2. The species colonized several floodplain lakes that were hydrologically connected to the river Meuse. Colonization of the main stream and flooding are expected to accelerate the dispersal of the species as well as new introductions. A risk assessment of the species was performed using the Invasive Species Environmental Impacts Assessment (ISEIA) and Harmonia+ protocols. The risk score according to the ISEIA protocol was 10 out of a maximum of 12 (moderate risk). In combination with its isolated populations, the species was classified as a B1 species, indicating that the species classified for the watch list in the Netherlands. The Harmonia+ assessment confirmed a moderate ecological risk and introduction risk of the species. Uncertainty was rather high due to lack of data on human health effects. Trade of the species should be regulated and public awareness of its impact ought to be increased to prevent further spread in Europe. There is an urgent need for research concerning the effects of the species on native biodiversity, ecosystem functioning and for feasible eradication or population control options.

NOTES

Development of a Regional Surveillance Plan for the U.S. Waters of the Laurentian Great Lakes

W. Lindsay Chadderton[1], *Gust Annis*[1], *Andrew J. Tucker*[1], *Alisha Dahlstrom*[2], *Donna Kashian*[2], *Joel Hoffman*[3], *Annett Trebitz*[3], *Tim Strakosh*[4], *Steve Hensler*[4], *Mike Hoff*[4], *Jon Bossenbroek*[5], *Sarah Le Sage*[6], *Nick Poppoff*[7], *Robert Wakeman*[8], *and John Navarro*[9]

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The Great Lakes states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin are working with the U.S. Fish and Wildlife Service (USFWS) and U.S. Environmental Protection Agency (USEPA) to develop an aquatic invasive species surveillance plan for the United States waters of the Great Lakes, the connecting channels, and major tributaries up to the first barrier. This state and federal collaboration aims to develop a comprehensive plan that will guide future surveillance (and response) actions across the region and foster interagency cooperative management. Here we will describe the development process and the major components of the draft plan. The plan builds on a long term research and surveillance program undertaken by the USEPA and USFWS in the region. The US waters of the Great lakes are divided into 10 km^2 grid squares and these are ranked using surrogate measures of risk for the major pathways of introduction to provide a spatial site prioritization system. The system is then used to select and sort sites to identify survey priorities based on available resources, taxonomic priorities and sampling capacity. A species watch list was also generated from previous regional risk analyses and is used to provide guidance on which habitats and pathways to sample. Recommendations are provided regarding the most effective available survey methods and sampling designs for the range of priority species and habitats that were identified. Communication protocols and future research needs to refine or improve efficacy of sampling methods are also identified.

NOTES

Aquatic Invasive Species Monitoring in Wisconsin, U.S.A.

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Wisconsin's aquatic invasive species (AIS) monitoring program has strategically implemented AIS surveillance on lakes, streams and wetlands since 2010 to establish statistically valid baseline data on AIS distribution and initiate early response efforts. Almost 1,000 lakes were surveyed in 5 years to track the rate of AIS spread. In addition, a pilot project was implemented on over 500 stream reaches to help prioritize early detection monitoring. Efforts to develop a wetland AIS monitoring strategy were initiated and will be expanded upon in the future. This presentation will describe sampling methods, preliminary results, and important discoveries made during these various monitoring efforts.

NOTES

The Spread and Potential Iimpacts of Freshwater Invasive Island Apple Snails (*Pomacea maculata*) in Coastal South Carolina, USA

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[4]*Robert Dillon, College of Charleston*

The freshwater gastropod *Pomacea maculata*, native to South America, was first reported from the wild in the United States in 2002 and in South Carolina (SC) in 2008. The species is believed to have been introduced via the aquarium trade. The high fecundity and consumption rates of *P. maculata* may have negative impacts on native snail populations. *Pomacea maculata* may also harbor the parasite *Angiostrongylus cantonensis*, which has been found in other established populations and can cause eosinophilic meningitis in humans. A new survey of 100 randomly selected ponds distributed throughout coastal SC determined that the current distribution of *P. maculata* is restricted to previously known discrete populations. All ponds within a 0.5 mile radius of these established populations were surveyed to determine the extent of these localized invasions. These intensively surveyed areas were located in the West Ashley area of Charleston and a cluster of three locations near Myrtle Beach, SC. The West Ashley P. *maculata* population was also sampled biweekly to examine growth rates and abundances of snails and egg casings throughout the spawning season. All *P. maculata* egg casings encountered during surveys were destroyed, and all *P. maculata* observed were collected for genetic and parasite prevalence studies. Water quality data were taken at each surveyed pond, and other snail species encountered were collected to compare the abundance and distribution of *P. maculata* and native snails in SC. Although there was no latitudinal trend in native species diversity, eight snail species were found, including two new invasive species. As very little is known about *P. maculata* in SC, understanding the current distribution and possible secondary transfer mechanisms is important for preventing further spread and conserving healthy, natural ecosystems.

NOTES

Use of Unique Medium Pressure UV System Firstlight Energy's Shepaug Dam in Connecticut

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[2]*RNT Consulting Inc.*

In 1986, invasive dreissenid mussels arrived in Lake St. Clair of the Great Lakes in the ballast of a ship from Europe. The resulting environmental damage and costs to Hydro electric utilities have been extraordinary. Many Utilities had to use control strategies which rely on the application of chemicals to control the invasive mussels. In January 2007, the quagga mussels were discovered at Lake Mead. The discovery generated instant concern in the hydroelectric power plants as the negative impacts have been well documented in the Great lakes Region. The Bureau of Reclamation, one of the largest owners/operators of Hydro-electric power plants immediately embarked on a concerted effort to study numerous control methods, many of them not based on chemicals. The objectives of the effort were twofold: to ensure the mussels did not affect power generation or water delivery operations at Hoover, Davis and Parker dams, and to gather information that could be shared with other water facility owners and operators about the impact of the mussels in the South West and the success of the control strategies tested.

Based on the experience gathered by Reclamation. Firstlight Energy's Shepaug Dam decided to install and test a proprietary medium pressure UV system to prevent mussel settlement in the cooling water of the dam. This technology is considered safe for the water, the environment and present no hazard to the operating staff. Further, the installation and use of the medium pressure UV system does not require an NPDES permit, provides continuous control by preventing settlement and is non corrosive to the pipes.

NOTES

Human and Natural Correlates of Freshwater Invasive Species Occurrence

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Numerous studies have documented the important role human factors play in the introduction of aquatic species outside their historic ranges. Natural causes can also play a role in introductions with the subsequent expansion of novel established populations. The introduction and spread of invasive species raises concern among many scientists and conservationists that natural ecosystems are losing biodiversity and becoming homogenized. The goal of this study was to investigate factors that are correlated with the number of freshwater invasive species found within hydrologic basins of the southeast Atlantic region of the United States. To accomplish this, we analyzed a presence-only dataset of aquatic introductions aggregated spatially at the 8-digit hydrologic unit basin level, and looked for correlations with human and natural variables such as basin size, number of river miles, minimum winter temperatures, human population, housing density, number of highway miles, and boat ramp density. Invasive species are becoming an increasing threat to protected areas, potentially reducing their value for preserving biodiversity. To better understand this threat, we also analyzed the data to identify aquatic species that have invaded or are likely to invade protected areas within the southeast Atlantic region, based on hydrologic connectivity.

NOTES

Habitat Invasibility and Thresholds of Impact of the Green Crab Invasion in the Southern Gulf of St. Lawrence, Canada

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Fisheries and Oceans Canada

Most studies of green crabs include limited information on the pre-invasion state of the ecosystem. The present three year study examines the effects of the green crab invasion on well-studied ecosystems (Kouchibouguac and Bouctouche in New Brunswick and St. Mary's Bay in Prince Edward Island, Canada). The vulnerability of different components (epi-benthic invertebrates, molluscs, estuarine fish communities and macrophytes) of these ecosystems at various trophic levels was examined and indicators of the effects of green crabs on these components were sought. An experimental fishery was also conducted to determine whether these effects can be mitigated by removal (fishing) of green crabs from these ecosystems. Preliminary results show a natural decrease in the abundance of green crabs in each ecosystem examined, which was most likely not induced by an experimental fishery.

NOTES

Engaging Youth on the Impacts and Implications of Aquatic Invasive Species on the Health of the Intertidal Zone in Placentia Bay Newfoundland

Kiley Best[1], *Nicole Hynes*[2], *Cynthia McKenzie*[3], *Kyle Matheson*[3], *Terri Wells*[3], *Tiffany Martin*[1]
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In October of 2014 a group of collaborating fisheries and outreach organizations and educators developed a field lab for high school students in Marystown Newfoundland to learn about the impacts of aquatic invasive species (AIS). The students were given a presentation by experts on invasive species risk in Newfoundland waters. This information included how to identify marine invasive species, mechanisms of spread and prevention. They then spent the day at a nearby beach which has been invaded by green crab *Carcinus meanas* participating in the collection of crab using a beach seine and crab traps. There was also a demonstration on green crab internal and external anatomy and biology. They then split into teams and collected data via transects to quantify all species diversity and collect green crab along the intertidal zone of Spanish Rooms' beach. The students were not only participating in a curriculum based activity with results presented back in class but assisted in a stewardship project funded by Vale Inc. and the Food Fish and Allied Workers Union. This information was also used for a Fisheries and Oceans Canada green crab database. Efforts like this by teachers and students from local communities are essential to peak interest in young people on the wellbeing of our intertidal coastal zones while spreading awareness in the community coastal zone users and inspire students to pursue a career in the conservation of our oceans. The event was considered a huge success by all involved and most importantly will aid in decreasing the spread and new introductions of aquatic invasive species in Newfoundland waters.

NOTES

Updating and Implementing the AIS Management Plan for Wisconsin

Tim Campbell[1], *Bob Wakeman*[2]
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[2]*Bob Wakeman, Wisconsin Department of Natural Resources*

Wisconsin drafted its first aquatic invasive species management plan in 2002. The first management plan focused on creating and building the newly authorized AIS program. With changes in the invasion landscape and advances in AIS management, an update to Wisconsin's AIS management plan was needed.

The revision process started by creating a core team of key stakeholders that included multiple representatives from different divisions of the DNR, university representatives, and nonprofit organizations. A series of core team meetings established goals, strategies, and actions, while a review process engaged stakeholders from across the state.

The updated Wisconsin AIS management plan shifted the focus of the plan from building an AIS program to sustaining and advancing an AIS program. The plan is equally devoted to refining existing programs while addressing previously unaddressed invasion pathways. To bring the Wisconsin plan in line with plans of neighboring states, Wisconsin utilized a pathways approach in order to reduce redundancies and to better focus prevention activities. The end result is hopefully a plan that is meaningful and able to be utilized by all stakeholders.

NOTES

Games as Instruments of *Limnoperna fortunei* Prevention and Environmental Education in Cascade Reservoirs Region: Jaguara, Volta Grande and Igarapava, Located in Minas Gerais State/Brazil

Claudia de Vilhena Schayer Sabino[1], Andrea Carla Leite Chaves[1], ***Maria Edith Rolla***[1]*, Ludmila Vieira Lage[1], Marcela David de Carvalho[2]*

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[2]*CEMIG – Centrais Energéticas de Minas Gerais*

Limnoperna fortunei (Dunker, 1857) has caused severe impacts on natural environments altering native biodiversity, ecosystem structure and function, and on man-made structures, causing economic loses. *Limnoperna fortunei* is having a significant impact on the shallow water habitat in the region of cascade reservoirs ecosystem. The Brazilian electric power industry sector will suffer the greatest economic losses if golden mussel is allowed to spread. It's important educating stakeholders, other government departments as well as general public on the various vectors which may transfer golden mussel and why it is essential to prevent spread. Golden mussel surveying and consequently education for the public, means the prevention of problems to energy companies. This paper aims to present a didactic sequence on golden mussel. The production of this sequence is justified by research showing that teachers and students have difficulty understanding environmental issues, especially issues related to water. The purpose is to improve curiosity and stimulate learning in order to contribute to effective teaching-learning process on infestation probability, focusing on prevention, environmental impacts and health risks. Educational products shown here include: game and manual targeted to teachers with information about golden mussel and the game application in a classroom. These products offer current scientific information, using multimedia resources. The main aspects of the issue were addressed through short and callouts using simple language and easily understood associated with images that illustrate the information. It is expected that these materials can, through play activities, contribute to: (1) Bringing scientific knowledge from the classroom and the daily life of students and teachers; (2) Awakening the interest of students and teachers for water contamination problem; (3) contribute to the formation of individuals better informed and more active on environmental issues and related health; (4) Bring changes about the attitudes of teachers and students the subjects of research.

NOTES

Movements and Habitat Use of the Invasive Species *Lithobates catesbeianus* in the Valley of the Grote Nete (Belgium)

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Nine adult American bullfrogs (*Lithobates catesbeianus*) were implanted with an internal radio transmitter and tracked during one year in the valley of the Grote Nete (Belgium). The mean ± SD home range area for Kernel 50% was 15.00 ± 22.41 m^2. Shores of larger eutrophic ponds and small temporary pools in alluvial forest were chosen as habitat. The habitat used (MCP 95%) had an average area of 11,086.73 ± 12,239.00 m^2. The study revealed a mean action radius of 270.78 ± 199.17 m and individuals can move up to 740 m in a single displacement. A positive correlation between weight and distance covered within one movement was found, which could suggest that dominant individuals are capable to cover greater distances in search for an optimal habitat for reproduction, foraging or hibernation. These results show that the dispersion of the American bullfrog in a valley system as the Grote Nete can proceed very rapidly.

NOTES

Using Functional Responses in the Risk Assessment of Invasive Crayfish

Jaime B. Grimm *and Anthony Ricciardi*
Redpath Museum & Department of Biology, McGill University

Efficient management requires that invasive species expected to have the greatest ecological and economic impacts be prioritized for early intervention. However, accurate forecasts of high-risk invaders and invasion scenarios are impeded by a lack of predictive tools; most generalizations about the putative traits of high impact invaders are derived from post-hoc observations and are rarely experimentally tested. Furthermore, impact potential and invasiveness may vary greatly across closely-related species.

Introduced animals that are highly successful and that disrupt food webs are expected to have higher resource consumption rates. This hypothesis can be assessed by examining an invader's functional response – the relationship between its predation rate and prey supply. Here, we compare the functional responses of native and invasive congeneric crayfishes (*Orconectes* spp.) at multiple temperatures to test the prediction that invasive species with documented impacts in the field (e.g. the rusty crayfish *Orconectes rusticus* and spiny-cheeked crayfish *Orconectes limosus*) have higher maximum feeding rates than those without extensive invasion or impact histories.

NOTES

A National Comprehensive Website on Aquatic Invaders in the Marketplace – TakeAIM.org

Danielle J. Hilbrich[1]*, Alice A. Denny*[1]*, Anjanette E. Riley*[2]*, and Patrice M. Charlebois*[1]
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Nearly 200 aquatic invasive species (AIS) have become established in the U.S. via the organisms-in-trade (OIT) pathway. Because of this, the U.S. Aquatic Nuisance Species Task Force views this pathway as one of the three main avenues by which non-native species invade our waterways. Despite its importance, historically there has been no comprehensive, national resource of information for those associated with the pathway—individuals involved in the buying, selling and management of aquatic organisms. This resource gap makes it difficult for these audiences, as a whole, to take the steps necessary to prevent the spread of AIS via the OIT pathway.

To fill this gap, we created TakeAIM.org in partnership with university researchers, and state and federal agencies. This website is designed for managers, retailers, and practitioners including aquaculturists, aquarium hobbyists, anglers, teachers and water gardeners. It provides practitioners with key information including tips for preventing the introduction of AIS via subpathway activities. Because retailers have told us that it is difficult to keep current on which organisms are regulated in each state, we have included a database of all state and federal regulations related to aquatic organisms. The website also contains a nation-wide compilation of OIT outreach materials, and resources to help managers assess the risk of individual aquatic organisms. These and other resources contained within the website provide the necessary information for all audiences associated with the OIT pathway to help them take steps to reduce the introduction and spread of AIS.

NOTES

Determining the Effectiveness of the Clean Boats Crew an Education and Outreach Program aimed at Preventing the Spread of Aquatic Invasive Species in Lake County, Illinois

Danielle J. Hilbrich[1], *C. Miller*[2]
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In the Great Lakes Basin, over 180 nonindigenous species have established since the early 1800s. Introductions of nonindigenous species and their associated risks have increased over the years due to human population growth, the rapid movement of people and the alteration of the environment. Populations of aquatic invasive species can rapidly expand throughout the Great Lakes Basin and North America via transport by recreationalists. Overland transportation of trailered boats is one of the ways aquatic invasive species are spread to inland bodies of water. When boats and other recreational equipment are used in an invaded waterway there is always a possibility that aquatic invasive species can be transferred to an uninvaded waterway.

To prevent continued spread of aquatic invasive species through overland transport, Illinois-Indiana Sea Grant created an education and outreach program entitled Clean Boats Crew. The programs aims at preventing the spread of aquatic invasive species in Illinois and Indiana waterways. The program promotes a healthy ecosystems and a healthy economy by involving individuals in preventing the spread of aquatic invasive species.

The focus of this study is to determine the effectiveness of the Clean Boats Crew education and outreach program in Lake County, Illinois. In order to do this a field researcher conducted intercept surveys of recreationalists at four previously visited boat launches. The goal of the survey was to gather information about recreationist's beliefs and preventative actions for aquatic invasive species in addition to their interactions with the Clean Boats Crew education and outreach program. In total, 311 surveys were collected from recreationists during the summer 2014 season. Results of the survey will be discussed during the presentation.

NOTES

Eradication of Tench, an Invasive Fish New to Ontario

***Maria Jawaid**, Brad Allan and Jeff K. Brinsmead*
Ontario Ministry of Natural Resources and Forestry

In June 2014, the Ontario Ministry of Natural Resources and Forestry (MNRF) was informed of an infestation of Tench (*Tinca tinca*) in a private pond near Orangeville, Ontario. The pond is connected by a top draw water control structure to the Humber River watershed of the Lake Ontario basin. To date, this is the first and only known occurrence of Tench in the province, and it is inferred from the experience of other jurisdictions, that if Tench were to establish in Ontario, native fish and mollusc populations would be negatively impacted.

Efforts to contain Tench within the pond, with an eventual goal of complete eradication, were initiated soon after the discovery. To assist these efforts, a project plan was developed which would streamline eradication decision made in the field. A number of physical strategies to remove the fish were attempted in fall 2014 including: electrofishing, netting, and dewatering the pond. When these physical strategies proved insufficient, the pond was treated with the piscicide Rotenone in spring 2015. The chemical treatment appeared to be effective within 1 hour of application. Tench and other fish species of variable sizes were recovered from the pond, and the chemical appeared to have no impact on other non-fish species that were noted feeding on the dead fish during removal efforts. Approximately 35 kg of fish were removed from the site. While it is difficult to confirm with absolute certainty whether the Tench have been successfully eradicated, post-treatment monitoring of the pond and nearby watercourses in summer 2015 did not find any additional Tench. Post-treatment monitoring will continue during the 2016 field season.

NOTES

Designing and Testing New eDNA Markers for Aquatic Invasive Species

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Reliable and sensitive DNA markers are critical to environmental DNA (eDNA) monitoring programs. There are, however, unique challenges involved in designing such markers, including balancing the conditions required to ensure inclusiveness (detect all individuals within target taxa), exclusiveness (not detecting nontarget taxa), and assay sensitivity (detecting minute quantities of eDNA). Standard approaches for developing and amplifying DNA markers, including DNA barcode markers, are inadequate in that they assume genetic samples will be dominated by the DNA of the target taxa, whereas typical eDNA samples are very strongly dominated by the DNA of nontarget taxa. Additionally, in many cases the nontarget species tested for cross-reactivity with potential eDNA markers are closely related (e.g., congeners) to the target species; however, we have found that, contrary to expectations, less closely related may also cause nontarget eDNA detections. Here we present information on our past efforts to design conventional and quantitative-real time PCR markers for the eDNA of silver and bighead carp (*Hypophthalmichthys molitrix* and *H. nobilis*), our on-going efforts to design similar markers for black carp (*Mylopharyngodon piceus*), and new efforts to design eDNA markers for invasive aquatic plants of the genus Elodea.

NOTES

Identifying Geographic Pathways of Zebra Mussel Spread: Minnesota as a Case Study

Sophie Mallez *and Michael McCartney*
University of Minnesota

The zebra mussel (*Dreissena polymorpha*) is currently spreading in North America, causing severe economic and ecological impacts, such as dense aggregations in water intake pipes of industrial facilities, lakeshore property damage, extinction risk for native freshwater mussels and removal of 1/2 or more of the planktonic biomass in heavily infested rivers and lakes. Therefore, identifying geographic pathways of spread is crucial for determining the origin of infestations and understanding the invasion process to prevent further dissemination. The reliable identification of source populations is indeed essential to management and helps target where inspection and prevention activities might be concentrated. For that purpose, we used the invasion in Minnesota as a case study. Here, spread to new inland lakes continues to rise yearly, so potential benefits of targeted prevention are large (in other US states, inland spread has reached a plateau). A large sampling of inland and Great Lake sites, as well as streams and rivers was carried out in 2014 and 2015, resulting in more than 35 sampled locations. In order to perform population genetic analyses, we gathered and optimized a set of 12 microsatellite markers from the literature. The processing of individuals (DNA extraction and genotyping) is currently underway in the laboratory. Assessing the genetic diversity of invasive populations and their relationships to populations in other source and destination waterbodies will aid in identifying the "super spreader" lakes and pathways that are best candidates for focused prevention efforts.

NOTES

Management of a Marine Invasive Species: Trapping as a Method to Control Abundances of European Green Crab (*Carcinus maenas*) in Newfoundland

Kyle Matheson[1], *Cynthia H McKenzie*[1], *Scott Caines*[2]
[1]*Fisheries and Oceans*
[2]*Qalipu Mi'kmaq Organization*

Since 2007, when European green crab (*Carcinus maenas*) was discovered in Placentia Bay, Newfoundland (NL), Fisheries and Oceans Canada has monitored its population spread across southern and western regions of the province. Research has demonstrated green crab in NL prey on and compete with native organisms, and high abundances of green crab are linked to dramatic declines in eelgrass coverage and associated juvenile fish abundance and diversity. Such concerns have led to increased questions by harvesters and other stakeholders regarding methods to control increasing populations of green crab. Albeit cases of eradicating marine invasive species are rare, it is believed that populations can be controlled to the point where green crab are not disastrous to surrounding ecosystems and native biodiversity can be preserved or restored. In 2014, we began a large-scale, multi-year trapping experiment with the participation of local fish harvesters to demonstrate the capacity for local management of green crab populations. Eleven locations with varying abundances of green crab were initially selected and in each location a harvester deployed 30 traps baited with herring twice daily for 10 days (in two locations, harvesters trapped for 20 days). More than 10 000 kg of green crab were captured (over 2000 kg at one site) and we observed declines in catch rates up to 50%, but the initial target threshold of 3 crab/trap/day was not achieved. In 2015, the experiment focused on four locations to increase trapping intensity (60 traps/harvester) in areas that showed strongest previous declines. Furthermore, in 2015 a population mark-recapture project, followed by removal efforts, was conducted at one additional site. Analysis is ongoing and this presentation will discuss results from this study.

NOTES

A Proposed Framework for Quantitative Risk Assessments of Aquatic Invasive Species in Ontario

Sarah Nienhuis, *Tim J. Haxton and Jeff K. Brinsmead*
Ontario Ministry of Natural Resources and Forestry

The number of introductions of aquatic invasive species in Ontario is ever-increasing. Given the potential impacts and control costs associated with novel invaders, the identification and prevention of further introductions of invasive species is a priority. The risk assessment process provides an ideal framework to evaluate whether a particular species could become invasive and have adverse ecological impacts. Accordingly, there is a need to develop a scientifically defensible risk assessment framework for the province to inform and support future regulatory decisions and management actions. To date, the majority of risk assessment protocols employed by different jurisdictions are either qualitative (based on subjective expert opinion) or are semi-quantitative in nature, employing simple scoring systems to categorize risk levels based on ad hoc cut-off thresholds. In contrast, quantitative methods for risk assessments aim to reduce cognitive bias and provide objective evaluations of risk by employing statistical models to estimate conditional probabilities and incorporate uncertainty. Here we present a quantitative framework for conducting risk assessments for aquatic invasive species in Ontario that provides a standardized, transparent, scientifically defensible, and objective means of evaluating the likelihood of invasion and adverse impacts. The framework follows a questionnaire-style format complete with detailed guidance and examples to comprehensively address all stages in the invasion process (i.e. Arrival, Survival, Establishment, Spread, Impacts). Answers follow a standardized rating system, require selection of an associated level of uncertainty, and must be justified by presenting existing scientific evidence. Responses to the questions and their associated uncertainty levels are then incorporated into a hierarchical modelling approach using Bayesian inference to derive the probability that the assessed species could become invasive and have impacts on the receiving environment. The tool has been tested for several known and potential aquatic invaders in Ontario, and results are presented.

NOTES

Wisconsin's Framework for Aquatic Invasive Species Response

Amanda Perdzock[1], *Jeremy Bates*[1], *Maureen Ferry*[1], *Michelle Nault*[1], *Tim Plude1*, *Bob Wakeman*[1], *Erin Vennie-Vollrath*[2]
[1]*Wisconsin Department of Natural Resources*
[2]*The Nature Conservancy*

Wisconsin's Rapid Response Framework for Aquatic Invasive Species was developed in 2012 with the intent to aid resource managers responsible for responding to newly discovered populations of aquatic invasive species (AIS). This framework ensures that attention is given to all of the necessary components of an effective response: coordination, communication, public outreach and community-based partnership, planning, incentives and funding, science, information management, laws and regulations, resources and logistics. Since its inception, this framework has been applied to multiple case studies across Wisconsin. The presented poster outlines key steps of the department's framework, reviews case studies which this framework has been applied to, and discusses lessons learned since the inception of this framework.

NOTES

Review of Aquatic Invasive Species Disinfection Methods by Species

Amanda Perdzock[1], *Jeremy Bates*[1], *Maureen Ferry1*, *Michelle Nault*[1], *Tim Plude*[1], *Erin Vennie-Vollrath*[2], *and Carol Warden*[3]
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[2]*The Nature Conservancy*
[3]*University of Wisconsin Center for Limnology*

A literature review of over 75 peer reviewed sources of disinfection methods was conducted to guide the development of the Wisconsin Department of Natural Resources manual code. The Manual code directs Department staff on proper procedures to follow when working in and around water. Disinfection methods reviewed include steam cleaning, hot water, drying, chlorine, Virkon Aquatic, and freezing. Efficacy of each method was reviewed for a wide range of aquatic invasive species including macrophytes, algae, invertebrates, and fish pathogens. Major findings identified that steam was effective for all species and that increased concentrations of chlorine solution and Virkon Aquatic were more effective for most species. The review resulted in modifications to the Departments manual code and the development of best management practices.

NOTES

Innovative Solutions for Asian Carp Management

Kristine Pinkney, *Lauren Tonelli and Deb Sparks*
Invasive Species Centre

Asian carps are at the doorstep of Canada's waterways and finding ways to keep them out and manage them should they establish is top of mind for managers, researchers and policy makers. New ideas for prevention and management of aquatic invasive species, specifically Asian carps, are continually being researched and developed by experts in this field.

Canadian undergraduate students are an untapped source of ideas for new approaches and inventive solutions to the problems being faced by Canadian Asian carp management teams and authorities. The Invasive Species Centre collaborated with Fisheries and Oceans Canada, Ontario Ministry of Natural Resources and Forestry, the University of Toronto Scarborough, Queens University, Great Lakes Fishery Commission, Stantec Consulting, Tree Frog Environmental, and the Canadian Aquatic Invasive Species Network of Windsor University to plan and execute an event that would connect experts with undergraduate innovation and raise awareness of Asian carps.

The Asian Carp Innovative Solutions Competition provided students with the opportunity to explore and exhibit their innovative ideas which may be instrumental in the prevention, management or elimination of Asian carps in the Great Lakes. This competition was held in March 2016 and teams of students were tasked with developing an innovative solution to the Asian carp problem and presented their ideas to a panel of subject matter and academic experts. The winning entry is highlighted on this poster.

The competition also helped to raise awareness and increase knowledge about the issues surrounding Asian carps and the work being done to prevent their introduction and establishment in the Great Lakes. Students were required to research the current Asian carp situation and strategies for management which helped to inform this younger generation about the issues facing Canadian waterways. This information may inspire some of these undergraduates to pursue a career in invasive species management and control. The competition was widely promoted through Ontario universities, social media and distribution lists, and the event was open to the public.

NOTES

Impacts of New Zealand Mudsnails (*Potamopygrus antipodarum*) on Ecosystem Metabolism in a Cold Water Stream in Wisconsin, USA

Michael P. Shupryt *and Maureen M. Ferry*
Wisconsin Department of Natural Resources

Aquatic invasive species have colonized freshwater ecosystems across North America impacting structure and function of native systems. New Zealand mud snails (*Potamopyrgus antipodarum*) were recently discovered in Black Earth Creek, Wisconsin. We used publically available data on dissolved oxygen, temperature, discharge and solar radiation to estimate daily rates of gross primary production (GPP) and ecosystem respiration (ER) at three locations over a continuous four year period. As the first year of data was likely before the *P. antipodarum* invasion and one of the three sites is upstream of the known invasion, we used a before-after control-impact design to evaluate the impacts of *P. antipodarum* on GPP and ER. After correcting rates of GPP and ER with daily rates from the control site we found no significant change in GPP and a significant increase in ER of approximately 17 and 9 percent per year at each of the impact sites. Although we cannot causally link *P. antipodarum* to changes in stream metabolism our results indicate that ER increased, relative to a control site, in Black Earth Creek after invasion.

NOTES

Spatial and Temporal Distribution of *Dreissena polymorpha* Larvae in a Warm Monomictic California Reservoir

***Mark D. Sytsma**, Angela Strecker, Steve Wells, Rich Miller, Scott Wells and Chris Berger*
Portland State University

The vertical spatial and temporal distribution of the planktonic larvae, or veligers, of *Dreissena polymorpha* (zebra mussels) were described in San Justo Reservoir, a warm monomictic reservoir in central California. The reservoir was sampled eight times, at approximately monthly intervals between January and August, 2015. Plankton samples (5-L of reservoir water) were collected at one-meter intervals throughout the water column at two sampling locations using a peristaltic pump and silicone tubing. Plankton samples were concentrated using 64-µm mesh filters, preserved in final solutions of 70% regular ethanol buffered with tris(hydroxymethyl) aminomethane, and transported to Portland State University for microscopic analysis. The entire concentrated plankton sample was analyzed, and *Dreissena* veligers were assigned to one of three larval developmental stages: 1) straight-hinge, 2) umbonal, or 3) late-umbonal/ pediveliger, based on hinge development, overall shape, size, and other morphology.

Dreissena mussel spawning in San Justo Reservoir was initiated prior to 11 April 2015 as indicated by the presence of straight-hinge veligers in the water column on that date, however, there was a distinct onset to a spawning period in the late May to early June. Late umbonal/ pediveligers found during the late January sampling event were likely veligers overwintering from the previous year. Veligers were limited to the epilimnion regardless of stratification, and veliger densities were consistently low near the water surface. Veliger density for all larval developmental stages peaked 5- to 8-m below the water surface regardless of season and stratification. The density gradient at the thermocline influenced the vertical distribution of veligers within the water column, however, the same vertical distribution was observed during periods when the reservoir was isothermal. The dissolved oxygen concentration is likely a lower threshold for survival during stratification, and avoidance of ultraviolet light is one possible factor influencing the avoidance of surface waters.

NOTES

Asian Carp Canada Spot the Difference Poster Campaign

Lauren Tonelli, *Kristine Pinkney and Deb Sparks*
Invasive Species Centre

Asian carp are an ever growing risk to the Great Lakes due to their proximity in the United States and the threat of illegal importation. Outreach and education are vital tools to prevent invasive species from entering an area. Because managers are still in the prevention stage, with no established Canadian populations, it is important to ensure the public are aware and knowledgeable in how they can play a role in the protection of the Great Lakes. It is because of this that the Invasive Species Centre is conducting a *Spot the Difference campaign*. The campaign consists of three different graphics which compare two waterfront recreation scenes before and after a hypothetical Asian carp invasion. A children's version was published in Owl Magazine, a cottager targeted ad was placed in Explore Magazine, and a fishing and wildlife targeted ad was placed in Outdoor Canada Magazine. One of the graphics was also displayed as posters in key public areas. The purpose of this campaign is to increase awareness of the threat Asian carp pose in key demographics. By finding all of the differences outlined in the pictures they can easily see that established populations of Asian carps would be detrimental to water recreation. The differences depicted include:

- Silver carp jumping out of the water, inhibiting water skiing and boating;
- Loss of fish biodiversity;
- Decreased recreational fishing;
- Increased risk of algal blooms and therefore beach closers;
- Potential decrease in property values;
- Decrease in water quality;
- Loss of wetland habitat and wildlife (such as ducks and moose).

Human activity is a large factor in the spread of invasive species, such as Asian carp, and as such it is necessary to have a knowledgeable population that knows the risks and how to mitigate them. This campaign hopes to increase the awareness of the general public to one of the greatest threats to the Great Lakes.

NOTES

The Impact of Dissolved Oxygen and pH on Zebra Mussel Growth and Mortality in a California Reservoir

Tanya Veldhuizen[1], *Jeff Janik*[1], *Renata Claudi*[2], *Kelly Stockton*[3]
[1]*California Department of Water Resources, Division of Operations and Maintenance*
[2]*RNT Consulting*
[3]*KASF Consulting*

Juvenile and adult zebra mussel growth and mortality were measured both spatially and temporally in a stratifying reservoir. The study was carried out at San Justo Reservoir, located approximately 5 km southwest of Hollister, California in San Benito County. This warm monomictic reservoir has the typical limnology of many southwestern reservoirs, turning over only once each year, in the fall, becoming heavily stratified in the spring with low dissolved oxygen below the thermocline. In addition, San Justo Reservoir is primarily used for irrigation, resulting in lake level changes as water is withdrawn in the summer and fall and the reservoir is refilled in the spring from upstream sources.

The presentation will describe the growth rates of different size classes of zebra mussels exposed at different depth of the reservoir and their mortality when exposed to changing environmental variables in the reservoir. Mussels from five size classes (3-6mm, 10-12mm, 12-19mm, 19-25mm, and 25mm+) were harvested from the reservoir and incubated in mesh bags throughout the epilimnion and hypolimnion (5ft, 10ft, 15ft, 20ft, 25ft, 30ft, 40ft, and 50ft) for one year. Mussels were removed from the water each month to measure maximum shell length, volume, and mortality, and then returned to the same treatment bag for redeployment. Shell length was determined by photographing mussels on graph paper with high resolution photography and measuring the images with measurement software. Volume was measured in the field using volumetric displacement in a graduated cylinder. Mussels deployed in the epilimnion grew faster and had higher survival than mussels deployed in the hypolimnion.

The documented limits of dissolved oxygen will provide management tools for western reservoirs which may become infested by zebra or quagga mussels in the future.

NOTES

Intensive Sampling to Detect Newly Introduced Aquatic Non-indigenous Species

***Sharon Yong**, Mattias Johansson, Colin van Overdijk and Hugh J. MacIsaac*
Great Lakes Institute for Environmental Research (GLIER)

Newly introduced non-indigenous species (NIS) usually experience a lag time before the population grows to a detectable level. Management of the NIS during this lag phase provides better opportunities for eradication. However, low population density can prohibit detection by conventional methods. Increasing the sampling intensity can increase the chances of detecting a NIS at low population abundance. Here we examine this issue using the newly introduced zebra mussel, *Dreissena polymorpha*, in Lake Winnipeg. Zebra mussels were first found in the south basin of the lake in 2013. Zebra mussels can disperse via larval veligers, carried by water currents and macrophytes, as well as by movement of adult zebra mussels biofouled on boats and other structures. We explore detection of veligers across a south to north gradient using intensive sampling (100 samples per site) in Lake Winnipeg. We detected large numbers of veligers found in the south basin, and a small number of veligers in the north basin, indicating dispersal into previously unpopulated regions of the lake.

NOTES

Zebra and Quagga Mussels: Issues Relating to Infestations in Infrastructures and Open Waters

Part I: Biology, Environmental Requirements and Control of Dreissenid Mussels in Man-made Facilities

Renata Claudi
RNT Consulting Inc.

This workshop will cover:

- Life cycle of dreissenid mussels
- Environmental requirements for successful reproduction and survival
- Biofouling Issues caused by dreissenid mussels in structures such as:
- Intake systems
- Cooling systems
- Fire protection systems
- HVAC Systems
- Potable water treatment plants
- Fouling Prevention vs. Absolute Barrier
- Available Control Strategies
- Chemical
- Non-chemical
- Regulatory environment

NOTES

Zebra and Quagga Mussels: Issues Relating to Infestations in Infrastructures and Open Waters

Part II. Infestations in Open Waters

Daniel P. Molloy
University of Illinois at Champaign/Urbana and Molloy & Associates, LLC

This workshop will address a wide range of topics relating to zebra and quagga mussel infestations in open waters (e.g., lakes and rivers), including:

- Key impacts of infestations in water bodies
- Key factors determining the risk of:
  - an initial introduction occurring in a water body
  - a population subsequently becoming established and reaching high densities
  - the spread of the infestation to another water body
- Prevention, detection, and rapid response programs and the key elements of designing and executing such programs
- Why an "early" detection program is no guarantee that an initial mussel introduction into a water body will be spotted "early" enough for eradication (i.e., 100% elimination) to be achieved
- Key factors contributing to the rare cases of successful eradication
- Why reductions in their densities throughout entire water bodies is rarely a feasible option
- Current control options for reducing infestations in relatively small, high-value areas, like beaches and docks
- Current and future research directions

NOTES

Status of Grass Carp in the Great Lakes

Duane C. Chapman[1], *Jennifer Bailey*[2], *Amy J. Benson*[1], *Becky Cudmore*[3], *John Farver*[4], *Seth J. Herbst*[5], *Patrick M. Kocovsky*[6], *Andrew R. Mahon*[7], *Jeffrey G. Miner*[4], *Diane Knicks*[8], *Greg W. Whitledge*[9]

[1]*U.S. Geological Survey*

[2]*U.S. Fish & Wildlife Service*

[3]*Fisheries and Oceans Canada*

[4]*Bowling Green State University*

[5]*Michigan Department of Natural Resources*

[6]*U.S. Geological Survey, Great Lakes Science Center*

[7]*University of Notre Dame*

[8]*U.S. Geological Survey, Columbia Environmental Research Center*

[9]*Southern Illinois University*

Grass Carp is an invasive species that has been captured intermittently in the Great Lakes basin since the early 1980s. Since that time, nearly 100 individuals have been captured throughout the four lower Great Lakes basins, but Grass Carp have never been captured from Lake Superior. Some captured Grass Carp were sterile triploids produced in aquaculture, while many others were fertile diploids. Otolith microchemistry and stable isotopes data provide evidence that many of the fertile fish are progeny stemming from natural reproduction in the Great Lakes basin, particularly among those collected from the Lake Erie basin. Collaborative efforts between universities, and state, provincial, and federal agencies in the USA and Canada exist to continue to gain information on the status of Grass Carp throughout the Great Lakes basin. We summarize what has been learned from capture location, ploidy analyses, otolith microchemistry and stable isotopes, gonad histology and GSI, and age and growth analyses.

NOTES

Evaluating the Potential for Overwinter Survival of Young-of-the-Year Grass Carp in the Great Lakes Basin

Lisa Jones[1], *Andrew Drake*[2], *and Nicholas E. Mandrak*[2]
[1]*Fisheries and Oceans Canada, Asian Carp Program*
[2]*University of Toronto at Scarborough*

Establishment of aquatic invasive species are a leading threat to aquatic biodiversity. One of the most acute threats facing the Great Lakes is the introduction of Asian carps, which have potential to cause extensive changes to ecosystems and the fisheries they support. Grass Carp *Ctenopharyngodon idella* was introduced to the United States as a biocontrol agent and has since established reproducing populations in several rivers of the United States and now threatens to invade the Great Lakes. Recent triploid and diploid captures from the Great Lakes has highlighted the need to assess its ecological risk, such as the likelihood of species establishment following arrival and survival. Vulnerable periods during early life history, such as the onset of cold, winter temperatures, can influence survival and population dynamics and represents a potential critical limiting factor to establishment of these temperate fishes. We present model predictions for overwinter survival of young-of-the-year Grass Carp under varying temperature regimes for each of the Great Lakes. These results will better inform ecological risk and the overall probability of establishment of Grass Carp to the Great Lakes basin.

NOTES

Corridor Between Lakes Huron and Superior: Potential Pathways for the Movement for Invasive Species

Lisa O'Connor[1], *Thomas Pratt*[1], *Evan Timusk*[1], *Nicholas Mandrak*[2]
[1]*Fisheries and Oceans Canada*
[2]*University of Toronto, Scarborough*

Historically, the St. Marys River, the connecting channel between Lakes Huron and Superior, was a free-flowing river with a powerful series of rapids in the Sault Ste. Marie area. The rapids were a barrier to movement for both human and many fish species, prior to human intervention in the last two centuries, which changed the river and provided new avenues for aquatic species movements between both Lake basins. As part of the threat assessment for the potential migration paths for Asian Carps in the Great Lakes, we setup a VEMCO hydrophone array in the St. Marys River in 2013 and 2014, above and below the potential barriers in the river (shipping locks, Compensation Works controlling the flow through the rapids, hydroelectric facilities), to determine where fishes may challenge or move between basins. We tagged a total of 152 fish (11 species) with VEMCO V9 hydroacoustic tags and tracked them between 2013 and 2014. In total eight fishes were detected moving from Lake Huron to Lake Superior using both the Canadian and US locks as well as through the Compensation Works, and of those tagged fishes, five were detected returning from Lake Superior to Lake Huron. Although the number of fishes detected moving between the basins was low, these results indicate that fishes can use several pathways to move between Lakes Huron and Superior. This highlights that preventing aquatic invasive species moving between connecting water bodies would be very difficult should Asian Carp gain access to the Great Lakes and a control strategy would be necessary to prevent Asian Carp from moving into Lake Superior.

NOTES

Ontario Surveillance Efforts for Asian Carp in the Great Lakes

***Chris Wilson**, Kristyne Wozney, Elizabeth Wright, Megan Belore and Brian Locke*
Ontario Ministry of Natural Resources and Forestry

In response to concerns of Asian carp potentially arriving in the Laurentian Great Lakes, the Ontario Ministry of Natural Resources and Forestry (OMNRF) has been using a combination of environmental DNA (eDNA) sampling, netting and electrofishing for the past several years to test for possible occurrences of Asian carp species before they can become established. Spring and summer sampling in 2013, 2014, and 2015 in Ontario waters of Lake Erie, Lake St. Clair, and tributaries used strategic targeting of habitats deemed suitable for spawning of bighead carp (*Hypophthalmichthys nobilis*) and silver carp (*H. molitrix*), as well as predicted summer habitat for both species plus grass carp (*Ctenopharyngodon idella*). Quantitative PCR assays with eDNA markers for all three species as well as black carp (*Mylopharyngodon piceus*) were used to screen for potential species occurrences. eDNA testing resulted in no detections of Asian carp DNA in 2013; isolated positive detections of bighead, silver, and grass carp eDNA occurred in 2014, but followup netting and electrofishing resulted in only one capture of a single grass carp in eastern Lake Erie. Although no other Asian carps were captured during seasonal surveillance netting, several grass carp were caught in eastern Lake Erie in 2013 and 2014, and efforts in 2015 were expanded to areas of Lake Ontario in response to separate captures of grass carp in that lake. The isolated captures of grass carp in both Lake Erie and Lake Ontario, as well as eDNA detections of bighead and silver carp in 2014, indicates the merits of surveillance efforts to inform and facilitate timely response actions to help prevent or deter the establishment of Asian carps in the Great Lakes.

NOTES

Assessing the Risks of Asian Carp Presence in the Chicago Area Waterway System: A Probabilistic Interpretation of eDNA Monitoring Results

***Martin T. Schultz**, Carl F. Cerco, Brian E. Skahill, Richard F. Lance, Mark R. Noel, Patricia K. DiJoseph, David L. Smith and Michael P. Guilfoyle*

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Two invasive species of Asian carp, bighead carp (*Hypophthalmichthys nobilis*) and silver carp (*H. molitrix*), are abundant in the Illinois River and elsewhere in the Mississippi River Basin. The Chicago Area Waterway System (CAWS) is the principal hydrologic connection between the Illinois River and Lake Michigan. In an effort to determine whether or not Asian carp are present in the CAWS upstream of an electric fish barrier, state and federal agencies conduct routine surveillance through a conventional fish sampling program and an environmental DNA (eDNA) monitoring program, which is designed to detect genetic material from a target species in environmental samples. These two programs have produced conflicting results. Conventional sampling has produced no evidence of Asian carp since early in 2010 despite thousands of man-hours of fishing effort. In contrast, eDNA specific to bighead and silver carp has been detected in a small fraction of eDNA monitoring samples. While Asian carp are difficult to catch when present in very low numbers, recent studies have also shown that the presence of Asian carp eDNA in the CAWS may be attributed to sources other than a live fish. Potential sources include bird feces, barge traffic, fishing nets, combined sewer overflows and Lake Michigan inflows. This presentation addresses the problem of how to interpret conflicting results from the two surveillance programs. Inference is accomplished by computing posterior probabilities of target species presence using a Bayesian network that has been parameterized using experimental data and the outputs of a hydrodynamic fate and transport simulation model. Prior probabilities of target species presence are calculated from data on conventional sampling effort. Evidence from eDNA monitoring is then used to update the prior probability of target species presence to a posterior probability. This presentation will describe how the Bayesian network is parameterized and inference is performed.

NOTES

Update on the Status of the IMO Ballast Water Convention

Christopher J. Wiley
Chair, IMO Ballast Water Group

2016 will likely be THE defining year for the Ballast Water Convention. As of this date 44 countries representing 32.86 per cent of the world tonnage have ratified. However, it would appear that sufficient countries have indicated they will be able to ratify shortly to put the Convention "over the top" at some point during the next year. The Convention will come into force one year after 30 countries representing 35% of the world tonnage ratify. As such, the IMO, ship owners and administrations will all be under pressure to ensure things are in place before the Convention comes into force.

Since 2004, the Ballast Water Group at IMO has produced an unprecedented amount of Guidance to be used for uniform implementation of the Convention. This Guidance has ensured that the ballast water technologies that have been developed to date, not only meet the biological standards required by the Convention but have been tested and approved such that they are safe for the ships, the crews and the environment.

For ship owners, it will be a key year for deciding on what Ballast Water technologies they will fit to their fleet, how they will finance the capital costs and where they will be fitted.(both physically onboard and in what shipyard). For administrations, training, and logistics will be required for enforcement actives that will be implemented.

The sooner the Convention comes into force and the sooner ships are fitted with technology to reduce the threat to the environment, the sooner science can show that the tremendous amount of work undertaken at IMO on this issue has paid off in showing that the shipping industry is an active part of the solution to the problem.

NOTES

Fednav's Experience Installing Ballast Water Treatment Systems Onboard Great Lakes Carriers

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The ballast water convention was agreed in 2004, twelve years ago. Some reports claims that as much as 15% of the world's merchant ships have treatment systems installed, but very few ships are using them. Although the Convention is very close to ratification, there are likely to be further delays as the marine industry is presently in its worst financial crisis of a generation. Then there is the matter of what technologies really work in practice and which may not; and there is the challenge of retrofitting existing ships (apparently less than 200 vessels worldwide have been retrofitted with a treatment system).

Considering the above, and considering the special circumstances of one of our main market, the Great Lakes, Fednav decided to act as early as 2005 and spent millions of dollars in testing treatment systems and methods. After evaluating the many methods of treatment available, Fednav conducted its own controlled tests involving an active substance (chlorine, which is widely used worldwide). The conclusive tests provided the confidence needed to announce, in April 2015, the purchase of twelve BWTS from a reputed Japanese manufacturer.

The presentation will focus on the risks and benefits of being an early adopter of treatment, and of the many challenges that remain.

NOTES

Using High Throughput Sequencing to Assess the Diversity of Propagule Pools Entering Ports Via Ballast Water

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Ballast water continues to represent a significant potential vector of non-native aquatic species introduction, despite increased global efforts to reduce risk of ballast water mediated invasions. Unfortunately, assessment of biodiversity transported in ships' ballast remains challenging and costly, and broad estimates of the propagule pools entering ports have been limited to a small number of studies due in part to the time, expense, and expertise required to evaluate samples at the highest possible taxonomic resolution. Here we employ high-throughput sequencing to assess the diversity of propagule pools entering three major US ports over a period of several years. Ballast water samples were collected from 162 ships entering Chesapeake Bay; Galveston, Texas; and Valdez, Alaska between 2012 and 2014. Representative DNA sequences were obtained from individual samples using the Illumina MiSeq platform. We generated sequence data from both the nuclear 18S small subunit rRNA (18S) and the mitochondrial cytochrome C oxidase subunit I (COI) genes using previously described universal primers. High quality sequences were used to develop taxonomic profiles based on assignment of operational taxonomic units (OTUs) employing standard bioinformatics approaches, and these data were analyzed to assess the accumulation of biodiversity introduced to recipient ports at multiple levels, including within ballast tanks, among tanks on individual vessels, across vessels, and across source regions. We also generated estimates of the cumulative species pools entering the three study ports over the sampling period. These analyses demonstrate the potential utility of high-throughput sequencing for understanding the transport of aquatic biodiversity via ballast water or other important vectors of non-native species introduction.

NOTES

Evaluating Risks Associated with Ballast Water Release by Domestic Vessels Transiting to Canadian Arctic waters

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Although regulations exist for international ships, domestic vessels navigating between ports are currently exempt from ballast water management regulations. Currently, much of the domestic ballast released in the Arctic is brought in by ice-class vessels capable of travelling throughout much of the year. These vessels frequently conduct voluntary exchange in northern Canadian coastal waters to reduce the risk of non-indigenous species (NIS) introductions; however there are questions regarding the effectiveness of exchange and how this varies by season. To address these questions, a 3-year study aimed at better understanding risks associated with the currently non-regulated domestic shipping pathway was recently initiated with the *MV Arctic*, a domestic vessel that regularly transits (from June-February) between Quebec City/Montreal and Deception Bay, Quebec (Nunavik). Objectives are to: 1) evaluate seasonal variation in plankton abundance and diversity within ballast to assess seasonal changes in risk for introduction of NIS through ballast release; 2) experimentally evaluate efficacy of voluntary exchange by comparing plankton communities before and after ballast exchange in control tanks (unexchanged water) as well as from tanks exchanged at two different locations. Preliminary results from the first year of sampling will be presented. Information from this study can improve our abilities to understand and manage ballast-mediated species introductions, help guide voluntary ballast management practices by industry and feed into regulatory decisions by Transport Canada.

NOTES

Survival of Hull Fouling Organisms During and After Voyages to the Canadian Arctic

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Vessels' hull fouling is a major transport vector of nonindigenous species in marine ecosystems globally. Many marine species attach to external surfaces of vessel hulls and can dislodge and/or reproduce at subsequent ports; however, very few studies have evaluated the veracity of this vector in the Arctic. Arctic sea ice may scrape hulls, negatively impacting fouling organisms; conversely, scraping or abrasion may release fouling organisms into the water, thus increasing introduction risk. To determine whether fouling organisms can survive transits to the Canadian Arctic, we conducted underwater surveys of eight military vessels immediately before, during, and after Arctic transits between 2008 and 2012. For each vessel, we collected hull fouling samples first in Halifax, Nova Scotia, secondly (when possible) in Iqaluit, Nanisivik, or Resolute in Nunavut or Churchill in Manitoba, and finally in Halifax to characterize abundance and composition of fouling organisms before and after Arctic transits. We found that both species abundance and richness decreased significantly during and after Arctic transits. Sessile organisms generally have higher survival rates than mobile species. We identified a total of 288 taxa in collected samples, including seven non-indigenous species. One nonindigenous nematode taxon, *Geomonhystera sp.*, was found in samples collected before, during, and after Arctic transits, suggesting that the taxon is capable of surviving conditions during Arctic voyages. Collectively, our results suggest that hull fouling may be an important vector for range expansion of native temperate species into the Canadian Arctic.

NOTES

Comparing Analysis Techniques of High-throughput Sequencing for Asian Carp Monitoring

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Effective early detection strategies are necessary for managing aquatic invasive species (AIS). Traditional efforts to detect AIS at low abundance to identify their invasion front use morphologic characteristics for taxonomic identification of acquired samples. These traditional methods can be time consuming, limited by cryptic morphological characteristics, or the AIS can be present at a low enough density to avoid capture altogether. An alternative method for monitoring AIS is using environmental DNA (eDNA) analyzed with standardized DNA markers (often termed barcodes) coupled with high-throughput sequencing (HTS). These barcodes allow ichthyofauna taxonomic identification, regardless of morphological characteristics. We tested the agreement between fish census data to HTS signal near Roush Lake, Indiana, to validate HTS barcoding as a monitoring tool to detect the presence of multiple invasive fishes. Water samples were collected before the drawdown of a large stilling basin and fish DNA was amplified using several common barcode markers. Amplicons were then processed using HTS. Census and biomass estimates were determined during the drawdown as fish were removed from the stilling basin. The eDNA signal and biomass data for all fish species, including the invasive bighead and silver carps, were compared. Refining collection and processing methodologies for the identification of ichthyofauna present in eDNA samples can increase confidence in HTS results. This study shows that HTS can be a useful tool for AIS detections.

NOTES

Early Detection Surveillance Methods for Asian Carps in the Canadian Great Lakes

David Marson *and Becky Cudmore*
Fisheries and Oceans Canada, Asian Carp Program

Fisheries and Oceans Canada's Asian Carp Program has been created in response to the threat of invasion by Asian carps in the Canadian waters of the Great Lakes. To address the threat of Asian carps, Fisheries and Oceans has developed an early detection surveillance program. Early detection sampling techniques combine both traditional sampling gears, as well as environmental DNA sampling. A variety of traditional gears are being incorporated into the surveillance program and, for consistency, many of the deployment techniques have been coordinated with the current Asian carp sampling practices by US state and federal agencies. This presentation will highlight the steps taken in the development and delivery of Fisheries and Ocean's Asian Carp Program, from early detection site selection, to sampling gear and techniques used to target Asian carps.

NOTES

Lessons Learned from Grass Carp 2015 Responses in the Canadian Great Lakes

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Fisheries and Oceans Canada, Asian Carp Program

All four species of Asian carps, Grass, Bighead, Silver and Black carps, pose a threat to the habitat, ecology and fisheries of the Great Lakes. There are no established populations of Asian carps in the Canadian waters of the Great Lakes and all four species are equally unwelcome in Canada. Prevention activities are a key focus of Fisheries and Oceans Canada's Asian Carp Program and this include the response to Asian carp captures to remove individuals from the waters before they have a chance to establish. The 2015 field season saw the greatest number of Grass Carp ever captured in the Canadian waters of lakes Erie and Ontario, including the first known diploids. Lessons learned from implementing responses, including under Incident Command System protocols will be presented.

NOTES

Law Enforcement Insights to Improve Coordinated and Effective Fishery Management

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In the Great Lakes basin, law enforcement is an integral part of the fishery management process, where authority to manage the fishery is shared among eight states, the Province of Ontario, and Native American tribes through a process identified in A Joint Strategic Plan for Management of Great Lakes Fisheries. One key aspect to the successful enforcement/management relationship is recognition that the role of enforcement is not limited to the field. Successful fisheries management requires involvement of enforcement throughout the management process to ensure that management objectives, regulations, and the expected role of enforcement are clearly defined and commensurate. Perhaps nowhere is this principle more true, and more tested, than in the Great Lakes basin, where the world's largest source of freshwater and a fishing industry that is worth more than $7 billion annually, is only as protected as the weakest, least enforced, and/or most violated regulation among the several jurisdictions.

To illustrate this point, the potential introduction of invasive grass carp to the Great Lakes basin through the baitfish pathway is examined. This case study illustrates regulatory conflicts that often exist throughout the basin. Variations exist not only among regulatory components but also in the authority of various agencies, the process by which regulations are developed, and the entity responsible for carrying out various provisions of regulations.

The Great Lakes Law Enforcement Committee is working with the Council of Lake Committees – comprised of senior level fishery managers from each jurisdiction's fishery management agency – to identify and amend regulatory inconsistences, legislative gaps, and ineffective enforcement mechanisms in each jurisdiction's regulations that collectively contribute to an increased risk of intentional and accidental release of aquatic invasive species.

NOTES

Assessing Introduction Risk Using Species' Rank-Abundance Distributions

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Mixed-species assemblages are often unintentionally introduced into new ecosystems. Analysing how assemblage structure varies during transport may provide insights into how introduction risk changes before propagules are released. Characterization of introduction risk is typically based on assessments of colonization pressure (the number of species transported) and total propagule pressure (the total abundance of propagules transferred) associated with an invasion vector. Generally, greater colonization pressure and/or propagule pressure represents greater invasion potential following introduction. Here, we extend these traditional summary statistics using rank-abundance distributions to examine how assemblage structure changes temporally in ballast water of ocean-going ships. Rank-abundance distributions and the relationship between colonization pressure and propagule pressure varied widely between trans-Atlantic and trans-Pacific voyages, with the latter posing a much lower risk than the former. Responses also differed by taxonomic group, with invertebrates experiencing losses mainly in total propagule pressure, while diatoms and dinoflagellates sustained losses primarily in colonization pressure. Paradoxically, open-ocean ballast water exchange increased introduction risk for dinoflagellates by uptake of new species or supplementation of existing ones.

NOTES

Ballast Water Sampling using Proportional Flow Control: Evaluating the Utility of External Ultrasonic Flow Meters in the Shipboard Environment

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Ballast water management systems that treat ballast water to meet standards for the allowable number of living organisms must undergo testing to obtain Type Approval, in which, among other parameters, the number of living organisms in the ballast discharge is measured. Similarly, the ballast discharge of ships in service will be subject to compliance monitoring from Port State Control to ensure the density of live organisms does not exceed regulatory limits. Measuring rare populations, such as the low densities of living organisms allowed by the regulations, requires a sampling approach that is representative of the volume of interest. To sample organisms ≥50 µm, this necessitates sampling of large volumes of water (on the order of cubic meters). These requirements dictate that sample flow must be proportional to the ballast flow being sampled, even though a discharge may occur over a long period, and discharge flows can vary or start and stop in conjunction with cargo loading. Proportional sampling requires that the sampling device monitors the ballast discharge flow and that information is used to control the flow. However, there is no provision for ships to provide a means to accurately measure ballast water flow for a sample collection device. A study was conducted to assess the performance of external ultrasonic flow meters that can be installed on ships' ballast piping for flow measurements. Here, external flow meters were installed at multiple locations in a ballast main pipe, and their stability and accuracy were compared with inline sensors. Additionally, the capture efficacy of organisms was evaluated when sampling using constant flow versus proportional flow.

NOTES

Comparison of Sampling Devices and Analytic Methods for Ballast Water Compliance Testing

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The Convention for the Control and Management of Ships' Ballast Water and Sediments (2004; BWMC) aims to minimize the transfer of harmful aquatic organisms in ships' ballast water. The BWMC requires compliance with standards limiting the number of living organisms of specified size classes that are released with ballast water discharge. The BWMC is still not in force, in part because there is some doubt about the reliability of the existing compliance monitoring methods. Some promising approaches for sample collection and analysis have been developed, but these methods need further study in the field to examine their accuracy and precision.

To address this gap, a voyage was undertaken by 20 international researchers on board the RV Meteor from June 4-15, 2015, from Cape Verde to Hamburg (Germany). During this time 28 trials were conducted to evaluate three ballast sampling devices (plankton net and 2 sampling skids) and a number of analytic devices (>200µm: 1 technique, >50µm: 5 techniques, >10µm and <50µm: 10 techniques, bacteria: 6 techniques). Water samples were collected using paired sampling devices and analyzed in parallel by all analytic methods to determine whether results were similar between devices and whether quick, indicative methods offer similar results to standard, time-intensive testing methods (e.g. microscopy) or high-end scientific approaches. Further, each analysis was completed in triplicate to better understand the error associated with each method. This presentation will highlight results from this voyage and future directions.

NOTES

How Effective are Size-separation Techniques for Concentrating Live Organisms ≥10 µm and <50 µm?

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Determining, with accuracy, living organism assemblages in ballast water is critical for verification testing of ballast water management systems and shipboard compliance testing. Organisms in ballast water may be sparsely distributed, especially following treatment, and they are typically concentrated prior to analysis by screening water through monofilament screen or membrane filters. These filtering methods do not provide perfect size fractionation due to factors including: organism morphology (shape and pliability) and physical stressors (shear forces and pressure gradients) on organisms. Such factors can cause cell loss and underestimations of organism concentrations, regardless of the analytical approach used to quantify them. The research goal was to determine the retention efficiency (*RE*) of mesh netting and membranes typically used in analyses of ballast water samples for organisms ≥10 µm and <50 µm. A series of laboratory experiments was performed to examine: (1) the capture efficiency of ambient marine plankton and laboratory microalgae cultures (including chain-forming species), (2) the relative performance of different mesh types and filtration procedures, and (3) microalgal physiological changes (as measured by variable fluorescence) following filtration. Measurements (microscopy counts and variable fluorescence) indicated high *RE* (>90%) of live cells regardless of origin (cultured versus ambient cells) and body configuration (single-cell versus chain-forming), although unicellular organisms near the 10-µm size threshold showed lower *RE* than chain-forming organisms (80% vs. 90% respectively). The comparison of filtration approaches revealed a decrease in screen opening did not always result in higher *RE*. No significant physiological changes were recorded when comparing the variable fluorescence measurements for all filtration and control samples. These studies demonstrate high and consistent *RE* of mesh netting.

NOTES

Development of a Novel Platform to Control Filter-feeding Aquatic Invasive Fishes

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United States Geological Survey, Upper Midwest Environmental Sciences Center

Two invasive fishes, silver *Hypophthalmichthys molitrix* and bighead carp *H. nobilis*, have spread throughout the Midwestern United States and currently threaten the billion dollar fisheries of the Great Lakes and Upper Mississippi. Both of these fishes are prolific spawners, fast growing and efficient filter feeders and as such they can dramatically alter aquatic ecosystems. Presently, resource managers are limited to rotenone or antimycin-A to control these aquatic invaders, which impact all species present in the system including those that are ecologically and/or economically important. A management control tool that is more "carp-specific", or a method to more specifically deliver currently registered control chemicals, is highly desirable. A targeted delivery system which exploits their planktivorous feeding habits and unique digestive enzyme characteristics has potential for greater selectivity than the current piscicide applications. Using technologies developed by the aquaculture and food industries, we are developing a micro-particle to selectively deliver control agents to both silver and bighead carp, while minimizing impacts on native fishes. Through several formulations, we have identified a micro-particle that is of the appropriate size that silver carp and bighead carp will consume. The micor-particle laden with antimycin-A has demonstrated specificity to silver carp and bighead carp in laboratory studies. The development of this micro-particle may alter the way resource managers control aquatic invasive species and allow for a more species-specific approach.

NOTES

Examining Non-physical Barriers for Fish Movement: Electricity, Water Gun, Boomers, Bubble, Sound, Alarm Cue, and Light

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When dealing with invasive species, permanent barriers may be best in preventing fish movements; however, they may not be feasible due to various logistical constraints and/or costs. Alternatively, various non-permanent barriers using electricity, light, sound, pressure, and bubbles are being developed and deployed in efforts to limit the spread of aquatic invasive species or to achieve fish guidance and conservation. However, effectiveness of these barriers is quite variable, and testing is often lacking or limited to small-scale lab settings. To evaluate the effectiveness of non-permanent barriers in preventing fish movement, we conducted lab trials and mesocosm studies in a large boat slip near Hamilton Harbour, Ontario, Canada. In 2014-2015, we deployed 12 acoustic receivers and tracked over 300 tagged freshwater fishes in the boat slip, which was divided in half by non-permanent barriers such as acoustic water gun, seismic boomer plates, electric barrier, bubble barriers, underwater speakers, underwater lights, and delivering alarm cue. Our results indicate that fishes were staying farther away from water gun and boomers when in operation. The results of 2014-2015 lab and field studies have important implications for evaluating management options to prevent the spread of aquatic invasive species such as Asian carps.

NOTES

Bigheaded Carp Behavior and Bioacoustics

Brooke J. Vetter[1]*, Kelsie A. Murchy*[1]*, Aaron R. Cupp*[2]*, Jon J. Amberg*[2]*, Mark P. Gaikowski*[2]*, Allen F. Mensinger*[1]
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Invasive silver (***Hypophthalmichthys molitrix***) and bighead (*H. nobilis*) carp dominate large regions of the Mississippi River Drainage, outcompete native species, and continue to expand northward threatening the Great Lakes. Silver carp are most notorious for their prolific and unusual jumping behavior. High densities of juvenile and adult (~25 kg) carp are known to jump up to 3 m above the water surface. Understanding silver carp jumping is not only important from a behavioral standpoint, it is also critical to determine effective techniques for controlling this harmful species. Field observations of silver carp jumping orientation and frequency were completed to better understand this behavior. Additionally, underwater recordings of outboard motors were analyzed to study the jumping stimulus. Controlled experiments, in restricted access outdoor concrete ponds (10 x 5 x 2 m), investigated the sensory biology of both carp species. The concrete ponds were outfitted with overhead cameras, speakers, and hydrophones. High frequency pure tones (500-2000 Hz) and field recordings of outboard motors were broadcast to bigheaded carp and their behavior was tracked. The fish habituated quickly to pure tones (after 1-2 trials) however, they regularly exhibited negative phonotaxis in response to outboard motor sounds. By alternating the speakers, carp movement was consistently directed away from the sound source to the opposite end of the pond. This research suggests that sound can be used to alter the behavior of bigheaded carp with implications for deterrent barriers or other uses (e.g., herding fish to increase harvest). Research was supported through the U.S. Geological Survey and University of Minnesota Duluth.

NOTES

Evaluating Common Carp Responses to Behavioural Barriers in a Mesocosm

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Major efforts have been undertaken to prevent the introduction and establishment of invasive Asian carps into the Great Lakes. The most likely pathway of Asian carp invasions is through dispersal, which requires passage across geographic bottlenecks such as canals. Non-permanent, behavioural barriers have been proposed as inexpensive means to restrict carp expansion past these bottlenecks while maintaining water flow and anthropogenic transport. However, little research has investigated the behavioural and avoidance responses of carps to visual and acoustic behavioural barriers. Our research examines Common Carp (*Cyprinus carpio*) behaviour in response to visual and acoustic stimuli.

An outdoor mesocosm with an environment similar to a canal was used to observe Common Carp movement, activity, cohesion, and spatial occupation. Common Carp (n=13) were implanted with acoustic telemetry tags and their behaviour was compared between exposures to visual, acoustic, and control behavioural barriers for 60-minute trials. Trials were run over both day and nighttime periods. Visual stimuli were represented by underwater 360o random flashing strobe lights at water depths of 3 m (n=6) and 6 m (n=6). The acoustic stimulus was constructed using a 50-1500Hz sweep, 50-1500Hz bandsweep, and a high quality recording of a marine engine, all of which were played through a single underwater speaker at a depth of 4 m and a sound pressure of 160db.

This study will provide a detailed examination of how common carps respond to proposed visual and acoustic behavioural barriers to movement. These findings may be used to inform policy decisions regarding the potential use of behavioural barriers against invasive species, such as Asian carps.

NOTES

The Effect of Temperature on Acoustical Deterrence of Bighead (*Hypophthalmichthys nobilis*) and Silver Carp (*H. molitrix*)

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Bighead carp (*Hypophthalmichthys nobilis*) and silver carp (*H. molitrix*) are invasive fish that were accidentally released into the Mississippi River and surrounding tributaries. For approximately the last 30 years, they have expanded their range throughout the Mississippi River drainage and are now at risk of entering the Great Lakes. Both species react negatively to sound and acoustic deterrents could be used as a practical tool within integrated pest management programs to manage these invasive species. However, anecdotal evidence suggests that water temperature may influence their behavioral response to sound, and therefore it is imperative to examine the effectiveness of acoustical deterrents over the range of temperatures that the fish will typically encounter in the Mississippi drainage. Phonotaxis behavior was assessed with broadband sound at four different temperatures (13° C, 18° C, 26° C and 32° C); and results suggest there is a decreased effectiveness of acoustic deterrents at lower temperatures. It remains unknown the extent carp swimming speeds are correlated to water temperature and diminished deterrence at lower temperature may be partially offset by slower swimming speeds. Nevertheless, results from this study have implications on the use of an acoustic barrier for bighead carp and silver carp.

NOTES

In Situ Observations of Silver Carp Behavior when Presented with Broadband Sound

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Bioacoustics has the potential as part of an Integrated Pest Management strategy for detection, deterrence and management of silver and bighead invasive carp. Controlled studies have shown that both species react negatively to play backs of broadband sound and will swim away from the source of this sound. Experiments were conducted on the Illinois River and a smaller tributary (Spoon River) to examine silver carp jumping behavior during acoustic stimulation in a natural setting. Underwater speakers were used to playback broadband sound from a stationary buoy or static and moving watercraft and the behavior recorded with video cameras. Sound alone was sufficient to stimulate jumping and the number of carps observed were directly correlated to sound intensity. Silver carp could be dispersed by sound both in the main channel of the river and in the smaller tributary with both upstream and downstream movement observed. Carp dispersion was confirmed by electroshocking and/or repeated stimulation using sound on the same areas of the waterways where sound was deployed, and fish were not detected until outside the stimulation zone. The size range of jumping fish varied considerably (< 10 cm to > 1 m) indicating that the sound is effective over a wide range of size classes. The results indicate that sound stimulation is effective at inducing jumping and dispersing fish in a natural setting and has potential for detection, deterrence and management of invasive carp.

NOTES

Complex Sound as a Deterrent to Bigheaded Carp Passage

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Silver carp and bighead carp have moved throughout the Mississippi River Basin, now making up a large proportion of the fish biomass within the Mississippi and Illinois Rivers. In the Illinois River, two major management techniques have been implemented for control, including commercial fishing, to remove biomass, and an electric dispersal barrier, to prevent upstream movement into Lake Michigan. Additional techniques are being developed with the goal of enhancing removal of fish or preventing upstream movement. One technique with great promise is complex sound. To determine the efficacy of complex sound (underwater recording of a boat motor) as a deterrent to bigheaded carp passage, we set up six bi-directional speakers across a 106 foot-wide mock lock chamber in a backwater of the Illinois River. Three paired trials (control trial with no sound followed by a sound trial) were conducted from 22 July - 2 August 2015. Thirty-two bigheaded carp were tagged with HTI acoustic transmitters and place on each side of the "lock" (16 per side) for each control and sound trial. Each trial was run for 24 hours followed by a 24 hour recovery period (to allow fish to exit the area). The sound of a boat motor was played continuously for 24 hours for each sound trial, then end block nets were then raised for 24 hours to allow fish to exit the area. The same study design was followed for control trials, but no sound was played from the speakers. An acoustic receiver array was erected to continuously monitor fish movement during the study, and an underwater hydrophone recorded the speaker output. We observed a behavioral response of bigheaded carp to the underwater sound compared to the control trials. Thus, with the right sound and speaker configuration, complex sound has great potential for controlling bigheaded carp movement.

NOTES

Evaluating Instruments Designed for Rapid, Shipboard Detection of Living Microorganisms in Ballast Water: An Initial Test of Compliance Tools

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Instruments designed to rapidly assess ballast water in shipboard environments are in development and (in many cases) production. The purpose of these instruments is to evaluate whether the sampled water complies with the national and international limits on the concentrations of organisms in ships' discharge. These instruments detect proximal characteristics of living organisms, such as the variable fluorescence of chlorophyll a or concentrations of cellular ATP. Whether results from these "compliance tools" correspond to time-consuming direct counts—performed by microscopy of organisms fluorescing after exposure to a set of vital fluorescent probes—is unclear. An initial, formal test of the relationship between several compliance tools and microscope counts began in summer of 2015 and continues. As part of this effort, field trials were conducted in freshwater, estuarine, and marine environments. These trials were designed to examine the fidelity of the relationship between the proximal measurements of compliance tools and the direct measurement of manual microscopy across different environments with different assemblages of organisms and water characteristics. Additionally, laboratory-based trials compared the compliance tools to the standard, microscopy-based approach using samples with two microalgal cultures (*Prorocentrum micans* and *Tetraselmis marina*). Several concentrations of the organisms were prepared and analyzed. The laboratory studies included samples amended with dissolved and particulate matter as well as samples representative of water following treatment by hypochlorite. The integrity of a compliance monitoring system may rest upon the performance of the shipboard instrumentation. Consequently, the process for evaluating the compliance tools should be thorough, rigid, effective, and follow procedures to ensure test and data quality.

NOTES

The Most Probable Number (MPN) Method to Quantify Organisms ≥10 µm and <50 µm: An Update

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In response to international and national actions to reduce the transport and delivery of aquatic nuisance species (ANS) in ballast water, an industry of commercial ballast water management systems (BWMS) using a variety of technical approaches has developed. Many use UV radiation to treat organisms ≥10 µm and <50 µm (nominally protists). At doses commonly used in BWMS applications, UV treatment is not intended to necessarily kill organisms instantaneously but instead renders cells non-viable, preventing reproduction. Thus, UV-treated organisms would not represent a threat from a biological invasions standpoint. Notably, to tally organisms to measure compliance to the discharge standard promulgated by the US, organisms are scored as "living" rather than "viable" due to (1) the inability to culture all potential organisms, and (2) the more protective and conservative criterion set by requiring cells to be dead rather than non-viable. In the US, the method prescribed by regulations to quantify living organisms ≥10 µm and <50 µm evaluates motility and the signal (if present) from two molecular, membrane-permeable markers. When the colorless markers enter a living cell, enzymes in the cell hydrolyze the probes to create a non-permeable product that fluoresces green when excited with blue light. Organisms exhibiting this fluorescence are scored as "living", as they show active enzymatic activity. It is likely that cells mortally damaged by UV—but still living when samples were interrogated—could have enzyme activity and thus be determined to be living. Therefore, an effort is underway to find an acceptable, additional method as an alternative. The most probable number (MPN) assay, which is a re-growth assay, is being considered by the Environmental Technology Verification (ETV) Program Technical Panel. This talk will trace the history of the discussions and provide an update on the latest activity.

NOTES

Uniform Response of Organisms in Different Phylogenetic Groups and Size Classes to Ballast Water Treatments

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Ballast Water Management Systems (BWMS) reduce organisms in ships' discharge water, thereby minimizing the risk of transporting aquatic nuisance species (ANS) across environments. In general, shipboard BWMS use a combination of filtration and biocidal agents or processes to treat organisms. A laboratory-scale evaluation was conducted to determine whether different major groups of marine planktonic organisms—the typical target of these treatments—respond to (simulated) treatment in a similar fashion. Samples of ambient organisms were concentrated from seawater, amended with dissolved and particulate matter to achieve regulatory test requirements, and supplemented with cultured microalgae. Then, the samples were treated by chlorination, UV radiation, or deoxygenation. Prior to and periodically after treatment, counts of living organisms in three size classes were made: <10 µm (represented by culturable, heterotrophic bacteria), ≥10 and <50 µm (nominally protists), and ≥50 µm (nominally zooplankton). With some exceptions in the <10 µm size class, organisms in each size class reacted comparably to treatments, regardless of whether the treatment resulted in a significant decrease in concentrations (relative to untreated controls). If this uniform response of organisms to treatment observed in this study is universal (i.e., occurring regardless of water conditions, organism assemblages, and scales of treatment), then the response of a single size class would be indicative of the responses of organisms in other size classes. However, these laboratory-scale studies may not predict the dynamics of sparsely distributed organisms, therefore, these preliminary findings should be verified in large-scale field or shipboard experiments.

NOTES

Efficacy of a NaOH-based Ballast Water Treatment System for Freshwater Ships: Mesocosm-scale Shipboard Trials

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The ballast water (BW) of freshwater tankers is an important pathway of secondary spread of nonnative species in the Great Lakes, however there are currently no type-approved BW treatment systems (BWTS) for freshwater ships in this region. The efficacy of a NaOH-based BWTS was tested aboard the Great Lakes bulk carrier *M/V American Spirit* in July 2015. BW was treated by adding NaOH to elevate pH to 11.5 or 11.7 for 48 h, then reduced to pH < 9 by sparging with carbon dioxide gas. The density of organisms after treatment at pH 11.7 met the 2013 Vessel General Permit discharge standards for all 3 organism size classes (< 10 µm, ≥ 10 µm to < 50 µm, > 50 µm). However, the density of organisms in the challenge water was below the IMO G8 shipboard uptake minima for indicator bacteria (*Escherichia coli* and *Enterococci*), and for phytoplankton, and was 40 to 60% below the minima for zooplankton; indicating uptake minima required by the IMO G8 do not reflect organism densities in the Great Lakes. To provide additional data on organisms in these size classes, procedures not in the current regulatory standards were added. Evaluation of total coliform and total heterotrophic bacteria indicated reductions of > 96% at both pH levels relative to intake densities. Initial observations indicated no live phytoplankton in the ≥ 10 µm to < 50 µm range at pH 11.7. ATP concentrations and FDA production rates demonstrated dramatic reductions in living biomass. Preliminary tests with the dinoflagellate-based QuickLite 200 Biosensor System indicated no residual toxic effects of the treated water; 7d whole effluent tests of residual toxicity are planned. Additional mesocosm-scale shipboard tests are being conducted in September 2015. This BWTS has the potential to become a viable method for treating BW released into freshwater systems.

NOTES

Evaluation of a Most Probable Number Method (MPN) Assay to Detect Living Organisms in Oligotrophic Water

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In attempt to reduce translocation of aquatic nuisance species (ANS), and ultimately the risk for biological invasions, discharge limits have been set for the number of living organisms allows to be discharged by ships. The Environmental Technology Verification (ETV) Program Protocol stipulates that quantification of organisms ≥10 µm and <50 µm be conducted by labeling organisms with fluorescent probes and counting them via epifluorescence microscopy to assess fluorescence and movement. This method targets organisms with intact enzymes and cell membranes. Some approaches used to treat ballast water, such as ultraviolet radiation, will not result in immediate cell death, but rather will render organisms unable to reproduce (but cells may still be living). To address this issue, an alternative method based upon the Most Probable Number (MPN) protocol has been proposed. A comparison of the proposed MPN method to the ETV method was conducted using ambient communities in oligotrophic water. Measurements were performed on organisms initially and after 14 days of incubation. Growth was observed in all dilutions and replicate tubes in 4 out of 5 trials, resulting in MPN estimates above the limit of detection (in this study, >2,100 mL^{-1}). An analysis of the organism size frequency distribution revealed size was reduced from a mean length of 17.1 µm (±10.6) to 7.3 µm (±3.9) to 6.0 µm (±2.7) from Day 0, to Day 7, to Day 14, respectively. The initial community at Day 0 consisted of a mixed assemblage of ambient organisms, while the community composition shifted to pennate diatoms by Day 7, which continued to be the dominant organism through the remainder of each trial. Due to overestimation of organism concentrations and changes in community composition by the proposed MPN Method, a revised method and alternative strategies to measure growth should be considered.

NOTES

Workshop: A Discussion of Ballast Water Sampling Approaches and Recommendations

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Both the United States and the International Maritime Organization (IMO) have identified numerical limits for the discharge of living organisms in ships' ballast water. To meet these limits, ship owners often choose to install a Type Approved Ballast Water Management System (BWMS). To obtain Type Approval, such systems must undergo both land-based and shipboard testing that verifies the performance claims and biological efficacy. Measuring the low number of organisms expected in treated ballast water requires the collection of a sample that is representative of the volume of interest. Further, the sampling and analytical volumes must result in measurements that have confidence intervals commensurate with the regulatory requirements. Such measurements for organisms in the ≥50 µm size class require the collection of cubic meters of water. Measurement of organisms in the ≥10 µm and <50 µm size class requires volumes on the order of liters. A suitable sampling system consists of an apparatus to extract the appropriate sample volumes from a ballast pipe (i.e., a sample port and a sample probe) and a sample collection device to process the sampled water. A meeting was convened to review current sampling methods, standards (i.e., ISO 11711-1), sampling systems, and the practices of groups developing and refining sampling systems. Commonalities and differences in the various sampling approaches were considered to determine the features necessary to achieve accurate and comparable data, with an emphasis on biological efficacy. A review of the approaches and recommendations from the meeting will be presented.

NOTES

A Revised Assessment of the Most Probable Number (MPN) Method for Enumerating Viable Phytoplankton Cells in Ballast Water Discharge

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In December 2015, the U.S. Coast Guard rejected the Most Probable Number (MPN) method for enumerating viable phytoplankton cells in ballast water discharge as an alternate to their prescribed method, which distinguishes living from dead organisms based on enzymatic activity and membrane integrity (assessed with vital stains), and motility. Key elements of the arguments for a live/dead classification and against viability assays using MPN are: i) modern techniques can discriminate live from dead cells reliably with a high degree of accuracy, whereas ii) the MPN method is subject to significant technical challenges including well-known difficulties culturing all types of microorganisms. Recent scientific findings temper these conclusions considerably. First, vital stains cannot be considered accurate for all species of phytoplankton. A comprehensive laboratory study of the vital stains, FDA and CMFDA, shows that error rates in classifying live vs. heat-killed phytoplankton cells exceeded 10% in the majority of 24 species tested, and four species stained more strongly when killed vs. alive — completely inconsistent with the method's assumptions. Second, the MPN method is much less vulnerable to methodological uncertainties than has been commonly thought. In particular, all species of phytoplankton need not be cultured in the conventional sense: a single viable cell in a dilution tube need grow only enough to be detected; inherently, this is a much lower technical hurdle than isolating and keeping a species in sustained cultivation over months to years. Further, the perceived problem of post-treatment repair and restoration of viability is inherently detectable using MPN. Uncertainties in MPN are compared to those in the stains/motility protocol. We conclude that with careful evaluation, MPN could serve as an effective method for assessing the viability of phytoplankton after ballast water treatment, no less protective of the environment than live/dead assessments using vital stains and motility.

NOTES

Understanding and Predicting the Impacts of Species Invasions: Old Challenges and New Approaches

Anthony Ricciardi
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Alien species are invading inland waters at increasing rates worldwide. Many of these invasions appear to have only minor ecological and economic consequences, whereas others have had dramatic impacts – including habitat degradation, disruption of water supply systems, fishery collapse, and native species loss. Predicting the outcome of an invasion is a longstanding challenge that is complicated by at least four factors: first, an invader's impact may vary greatly across time and space under the influence of environmental variables; second, it may be altered by interactions with overlapping human-driven stressors (e.g. disturbance, climate change) as well as other invaders; third, indirect effects are often poorly understood; and, finally, impact data are lacking for most invasions. These constraints have hindered the development of risk assessment tools for anticipating and prioritizing invasion threats.

Nevertheless, there are some promising but underused approaches to developing a more predictive understanding of invasions. For invaders with well-documented impact histories, data from multiple invaded sites can reveal predictable patterns that are relevant to risk assessment. In many cases, most of the spatial variation in the impact of an invader is generated by a few key physical habitat variables. Once identified, these variables can be used to construct simple statistical models that predict where impacts will be most severe.

General hypotheses can be developed and tested using experiments conducted in multiple systems that span a broad range of ecological contexts. Syntheses of data from such experiments suggest that high-impact invaders tend to 1) be phylogenetically distinct (that is, they have no close relatives) in the invaded region; 2) have higher resource consumption rates than resident natives; and 3) occupy habitats where the ambient temperature most closely matches their thermal growth optima.

NOTES

Metrics Based on Comparative Functional Responses and Abundance Reliably Predict Invasive Species Identities and Ecological Impacts

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Understanding and ultimately predicting the ecological impacts of existing, emerging and future invasive species is a research priority. However, this has been elusive when based on traditional species traits, such as r- versus K-selected species, fecundity, growth rates and trait plasticity. Ideally, predictive metrics should be easy to derive and applicable across taxonomic and trophic groups, also helping to unify invasion ecology, such as the current divide between animal and plant invasion ecology. Parker et al in 1999 (Biol Inv 1: 3-19) famously proposed the equation that: Impact = Range X Abundance X Effect (*per capita*), but there has been little advance in the development or usage of such a metric. Additionally, and unfortunately, invasion ecologists have until recently missed the classic equation describing the impact of a consumer towards a resource, where: Total Response = Functional Response (*per capita*) X Numerical Response, which is similar to the Parker equation. Here, I show that the functional response (FR) is strongly associated with the ecological impacts of invaders, with high impact invaders predictable from their comparatively high functional response curves; the corollary also holds true, with low impact of invaders characterized by relatively low functional responses. A further advance of this metric uses the abundance (AB) of invaders and natives as well as their functional responses, measured as maximum feeding rates, with a revised equation: Impact Potential = (FRinvader/FRnative) X (ABinvader/ABnative), where values above 1 indicate the degree of impact of invaders. Across many study systems, taxa and trophic groups, including animals and plants, both functional responses (FRs) and impact potential (IP) are consistent in their ability to identify high impact invaders. I propose that these metrics identify the underlying reasons for the success and impacts of invasive species and can form the basis of objective and reliable prediction in invasion ecology.

NOTES

The Use of Potassium Chloride to Control Zebra Mussels: Lake Winnipeg Harbours

Dan Butts
ASI Group Ltd.

In October 2013 zebra mussels were observed for the first time in the Province of Manitoba, in four isolated harbours, all located within the South Basin of Lake Winnipeg; Arnes, Balsam Bay, Gimli and Winnipeg Beach. At the time of the discovery it was unknown how colonization had occurred as mussel presence within Lake Winnipeg had not been previously documented. However, the onset of winter prevented further investigation of Lake Winnipeg to confirm this as the source. This left the Province in a difficult position as to how to proceed, because if the source of colonization had not been from the Lake, then theoretically infestation could still be prevented. With the limited information available, the Manitoba Conservation Authority determined that the best course of action was to attempt eradication in each harbor with the ultimate goal of preventing further proliferation into the greater lake during the spring of 2014.

The scope of work posed a very unique and challenging situation, given the location, open water nature and complexity of each harbour. ASI Group Ltd., which had successfully completed an open water eradication at Millbrook Quarry in 2006, was retained to develop and implement a treatment methodology.

ASI engineered a method to close off the harbours from the lake, to in effect create 5 small treatment areas which could then be infused with potassium via the addition of potassium chloride – KCl solution in to the water body. This unique approach allowed ASI to achieve and maintain the required K+ concentrations for a successful treatment.

NOTES

Use of UV Radiation Technology to Prevent Settlement of Quagga Mussel Larvae

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Dreissenid mussels are a non-native nuisance species in North America that can foul hard substrates, creating significant mitigation costs to remove. Current mitigation strategies can be effective at preventing adult colonization, though they tend to be costly, labor intensive, and reactive in nature targeting post-settlement mussels. Successfully inhibiting the settlement and establishment of adults by inducing mortality at earlier life stages may prove to be an effective means of control in flow-through hydropower facilities. Ultraviolet (UV) radiation technology is a non-chemical sterilization method used in the water treatment industry. Ultraviolet radiation does not alter water quality, has no significant by-products, no residual downstream treatment effects, is easy to operate, and is effective against most aquatic viruses, bacteria, and protozoans by inducing DNA and protein damage. Although previous studies have demonstrated the lethality of UV radiation on mussel larvae, more controlled research is needed to determine the specific effects of UV light and environmental factors on settlement success. This presentation will discuss the objectives of this study, which are to evaluate the effects of water transmissibility and UV-C and UV-B radiation dose to cause larval mortality and prevent settlement in a continuous-flow system. An estimate of operational cost for implementing UV technology in hydroelectric facilities will be determined and recommendations will be given as a part of this study.

NOTES

Evaluation of the Effects of Ultra-Violet Light Treatment on Quagga Mussel Settlement and Veligers at Davis Dam

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Dreissenid mussels are aggressive biofoulers that threaten water delivery and hydropower reliability. The use of medium pressure UV systems to control dreissenid mussel settlement in industrial cooling water systems is a desirable alternative to chemical treatments. This paper summarizes two experiments, carried out over two years, using a proprietary medium pressure UV system installed on a power generating unit at Davis Dam, AZ, USA. The first experiment tested quagga mussel (*Dreissena bugensis*, Andrusov, 1897) veliger settlement when exposed to a dose of 50, 40 and 20 mJ/cm². The second experiment tested settlement at 100 mJ/cm², and examined treatment mode of action, by evaluating veligers post exposure at 100, 50, 40, and 20 mJ/cm². Veligers of each life stage (straight-hinged, umbonal, and pediveliger) were examined for behavioral changes, physical damage, and immediate or latent mortality. Each dose was tested in the early and late summer to examine if seasonal variability impacted veliger response. All doses tested in the first experiment resulted in settlement reduction between 88 and 99%. The 100 mJ/cm² dose reduced settlement by 99%. Delayed veliger mortality was observed at every UV level, and is variable based on UV dose, season, and veliger size.

NOTES

Use of Electrified Fields for Dreissenid Mussel Control

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Dreissenid mussels (*Dreissena polymorpha* [zebra mussel] and *Dreissena rostriformis bugensis* [quagga mussel]) significantly disrupt aquatic ecosystems and their range continues to expand without effective tools to mitigate their impacts to open-water aquatic environments. Kolz et al. (1996) demonstrated that long-term exposure to electrified fields with voltage gradients as low as 2.5 V/cm caused zebra mussel mortality. Our study was designed to determine the voltage gradient required to induce dreissenid mussel mortality using acute exposures to high intensity electrical waveforms of up to 30 V/cm using alternating current (AC) and pulse direct current (PDC) at different water temperatures. A Midwest Lake Electrofishing Systems Infinity Control box connected to a 10 kVA isolation transformer was used to deliver the electrified fields to groups of 50 zebra mussels (n = 3) positioned in a fiberglass exposure tank. The delivered voltage gradient and electrical waveform were confirmed using a Fluke model 124S scopemeter according to the methods described by Kolz (1993). Exposed zebra mussels were held in a semi-recirculating culture system for 7-14 days after exposure before being assessed for survival. The results of the exposure trials will be presented including determination of the most efficient electrical waveform for potential use as a dreissenid mussel control tool.

NOTES

Microencapsulated BioBullets: An Effective Control Strategy for Invasive Mussels

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BioBullets are an effective control solution for biofouling zebra mussels, quagga mussels and Asian clams. This award-winning product is approved for use in UK drinking waters and is the favoured solution for mussel control by the UK water industry. The products have been successfully demonstrated in operational drinking water pipes with flow-through of up to 150 MLD (122 acre feet per day) and have also been used effectively in Spanish agricultural irrigation systems. The patented solution uses microencapsulation of active ingredients with food grade coatings. The mussels filter and accumulate the active ingredients without realising they have swallowed a 'poison pill'. Any uneaten particles are engineered to degrade within hours of entering the water, thus avoiding risk to recipient waters and non-target biota. A dedicated manufacturing plant has been built which meets all ISO compliance requirements. Having successfully developed and refined our products in the UK within one of the most conservative industries, we are now looking for opportunities to demonstrate our products in flow-through systems in North America and would welcome collaborations.

NOTES

Behaviour and Dispersal Potential in Invasive Fish Populations

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The successful establishment and expansion of invasive species may be linked to the behavior and dispersal tendency of particular individuals. To test the prediction that the boldest individuals with the greatest dispersal tendency would be concentrated in the invasion front, we compared the behavior, dispersal tendency of male round goby (*Neogobius melanostomus*) sampled from the expanding edge of their range with those sampled from an established area in a river system in Ontario, Canada. Behavior and dispersal tendency were assessed in an artificial flume 4 m in length. Round goby from the edge of their expanding range emerged from a shelter sooner and moved farther and faster in the flume. To further determine whether boldness and high dispersal tendency would be characteristic of successful invasive populations in general, we then compared these traits between pond pumpkinseed (*Lepomis gibbosus*) populations established from two native Canadian populations and two invasive populations originating in Spain. No significant differences in boldness or dispersal potential were found between pumpkinseed of native and non-native origin, but populations originating from lacustrine (lake and reservoir) environments showed significantly higher dispersal potential than those originating from fluvial environments. We hypothesize that bold individuals with high dispersal potential at invasion fronts facilitates further dispersal of the species, but does not ultimately favour the evolution of bold, high-dispersal phenotypes in an invasive fish population.

NOTES

Behavioural Variation Among Round Goby (*Neogobius melanostomus*) Individuals at Different Stages of the Invasion Process

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The success of non-indigenous species can be dependent on a several intrinsic, species-based mechanisms (i.e. genotype, high reproductive rates) and more external influences (i.e. conditions of new environment or predators present). More recently, it has been speculated that optimal behaviours such as increased flexibility and/or multiple behavioural types are required to facilitate the successful transition of a species between each stage of the invasion process. My study species, the round goby (*Neogobius melanostomus*), is a well-established invasive freshwater fish continuously expanding its range in the Great Lakes and its tributaries. The objective of my study is to investigate whether successful invasive species like the round goby exhibit a suite of expected behavioural traits and whether they vary across the source, established and invasion stage-dispersal phases of the invasion process. I sampled St. Clair River (SCR) in Southwestern Ontario as my source site (longest established in North America), and the established (river mouths) and invasion stages (upstream of the river) of three additional rivers, each differing in their time-since-invasion from SCR. I subjected thirty round gobies (adults and juveniles) from each population to a behavioral assay that tested for behavioural types on a boldness-to-shyness continuum scale, exploration in a novel environment, learning and habituation to a predator stimulus, manoeuvrability through a maze and overall dispersal distance. I tested the hypothesis that gobies at the invasion stage and from rivers most recently invaded share a similar "invasion syndrome" phenotype and are less flexible in their behaviours. By learning what behavioural attributes are more likely to be present at certain stages of the invasion process, one could potentially create a screening profile for the possible early identification of future invasive species and utilize specific eradication techniques to limit the species' population growth and impact.

NOTES

Life History Shifts in Invasive Populations: Nature or Nurture?

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Invasive fish populations often exhibit a suite of life history traits that differ from native source populations, however whether these differences are the result of genetic or phenotypic change is often unknown. For example, in the wild, invasive European Pumpkinseed (*Lepomis gibbosus*; a globally successful invasive freshwater fish) tend to mature at a younger age, have smaller adult body size, and higher reproductive allocation compared with native North American populations. Here, we use a common garden experiment to determine if the differences in life history traits expressed by native and invasive Pumpkinseed are the result of genetic differences, or purely a phenotypic response to the local environment. In 2008, we established breeding colonies in outdoor ponds in central Ontario, Canada, using Pumpkinseed from two native Canadian populations and two invasive populations from north-eastern Spain. These pond colonies allow us to compare life history traits among native and invasive Pumpkinseed reared under identical environmental conditions for several years. We expect pond-reared Pumpkinseed to exhibit more r- selected characteristics than their wild counterparts as a result of a phenotypic response to the experimental pond conditions. However, if the life history traits expressed in pond-reared Pumpkinseed continue to differ among native and invasive populations, then we can conclude that this pattern is likely the result of genetic differences that have been established within the ~120 years since European Pumpkinseed were first introduced. Preliminary results indicate similar growth trajectories among all pond-reared populations, however pond-reared invasive populations tend to have higher GSI than pond-reared native populations, especially during the second half of the spawning season.

NOTES

Changes in the Distribution and Abundance of Rainbow Smelt (*Osmerus mordax*) in Lake Winnipeg and the Nelson River, Manitoba, Canada, 1990s-2010s

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Rainbow Smelt (*Osmerus mordax*) were introduced into the Nelson River drainage basin in the 1970s and were first reported from Lake Winnipeg in 1990. They colonized Lake Winnipeg during the early 1990s and were first captured in four waterbodies in the lower Nelson River in 1996. By the early 2000s Rainbow Smelt were well established within Lake Winnipeg and were a major component of the forage fish community and the diet of Walleye (*Sander vitreus*) and Northern Pike (*Esox lucius*) in the lower Nelson River. Current data suggests that the abundance of Rainbow Smelt in Lake Winnipeg and the lower Nelson River has declined. We present information on catch-per-unit-effort and biomass of Rainbow Smelt based on gillnet data and trawl data from Lake Winnipeg and gillnet data from selected waterbodies within the lower Nelson River over time. Implications of changes in the abundance of Rainbow Smelt will be discussed.

NOTES

Sinking Water Soldier Permanently

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Water soldier (*Stratiotes aloides*) is an invasive perennial aquatic plant that is native to Europe and northwest Asia. The only known wild population in North America was found in the Trent Severn Waterway (TSW) in 2008 near the Hamlet of Trent River, Ontario. Water soldier forms dense mats of floating and submerged vegetation, and aggressively outcompetes native vegetation, and can significantly impede recreational activities, such as boating, swimming and angling. Water soldier has the potential to invade lake and river ecosystems throughout Ontario and the Great Lakes basin ecosystem – causing significant harm to biodiversity and affecting recreation, tourism and navigation in aquatic systems. To address this threat, an inter-agency working group, with representatives from the Ministry of Natural Resources and Forestry (MNRF), Ontario Federation of Anglers and Hunters (OFAH), Ministry of Environment and Climate Change (MOECC), Trent University, Lower Trent Conservation Authority, United States Army Corps of Engineers (USACE) and Parks Canada, was established and responsible for the development of the Integrated Management Plan for Water Soldier (IMP). The purpose of the IMP is to prevent new introductions to the province, and to address existing populations that threaten to invade provincial, national, and international waters. The IMP has three main objectives: 1) prevent the introduction and spread of water soldier to new locations in Ontario, 2) early detection and rapid response to new water soldier populations detected within Ontario, and 3) eradicate established populations of water soldier from public waters in Ontario. Utilizing the IMP, as well as best available science, the inter-agency working group is currently implementing the second year of a multi-year project that seeks to eradicate water soldier from the TSW.

NOTES

Great Lakes *Phragmites* Collaborative: A Collective Impact Approach to Non-Native *Phragmites*

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Rapid progression of non-native *Phragmites australis* (common reed) across the Great Lakes basin affects the biodiversity and ecological functions of coastal and wetland habitats, impairs the socio-economic value of wetlands and shorelines, places an increased financial burden on land managers, and threatens the extensive habitat restoration efforts funded through the Great Lakes Restoration Initiative and other restoration programs. The Great Lakes Phragmites Collaborative (GLPC) is a regional partnership established in 2012 to improve communication and collaboration and lead to more coordinated, efficient and strategic approaches to non-native *Phragmites* management, restoration and research across the Great Lakes basin. Prior to the establishment of the GLPC, resources on non-native *Phragmites* management were scattered and sometimes inaccurate, management was rarely ecosystem-based or adaptive, management efforts were uncoordinated and up–to-date research was not publicized and integrated into management practices. Administered by the U.S. Geological Survey - Great Lakes Science Center and the Great Lakes Commission, the GLPC uses the model of Collective Impact to address the large-scale and complex ecological issues resulting from non-native *Phragmites* invasion and guide the efforts of stakeholders engaged in management and research. With input from an Advisory Committee, the GLPC facilitates regional communication through a centralized web-hub, webinar series, and other user-driven products. Overall, it serves as a partnership to link people, information and action. Capitalizing on an interactive approach, the GLPC provides access to rigorous science and promotes network building among managers, government agencies, landowners and scientists. We present the organizational structure, goals and objectives of the GLPC, review the communication tools created to support efficient and effective management and restoration, and discuss research and adaptive management tools under development to address needs and knowledge gaps and improve coordination among and between scientists and managers.

NOTES

Collective Development of a Science Agenda for Managing Non-native *Phragmites australis* through Microbial Intervention

Kurt P. Kowalski *and Wes Bickford*
U.S. Geological Survey – Great Lakes Science Center

Management of non-native *Phragmites australis* (common reed) is a high priority for federal, state, and private resources managers throughout North America. Conventional management strategies are not sustainable at the landscape scale, so innovative approaches are being developed. Using principles of the collective impact model, an international group of scientists formed the Collaborative for Microbial Symbiosis and *Phragmites* Management (PSC) in 2013. This group sought to establish the current state of the science, identify research gaps, and develop a research agenda to guide and support research on microbial symbiosis to maximize collective progress toward an integrated *Phragmites australis* control and habitat restoration strategy. *Phragmites* harbors rich microbial communities comprised of both mutualists and potential pathogens. However, the specific roles and functions of most of these *Phragmites*-associated microbes have not been evaluated. Similarly, the steps needed to develop a management strategy based on symbiotic microbial relationships are unclear. The PSC published a recent paper highlighting a proposed science agenda that outlines four sequential steps and several tasks to guide the development of a microbe-based control strategy for *Phragmites*. First, an inventory of the microbes influential to *Phragmites* will identify the organisms to target for subsequent research. Second, a description of the benefits and roles of influential microbes will reveal microbial-plant symbiotic relationships that may give *Phragmites* a competitive advantage over native species. Third, select relationships can be targeted for control, and resulting management methods can be tested for effectiveness and feasibility in the final conceptual step. These steps target the microbial relationships influencing the competitive abilities of invasive *Phragmites* and describe principles and approaches useful for microbiome manipulations in other invasive species.

NOTES

Achieving a Consilience of Science and Stakeholders: An Integrated Aquatic Vegetation Management Plan for Lake Tahoe Keys Lagoons

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Invasive and nuisance aquatic plants have plagued the near shore areas and marinas at Lake Tahoe for over 25 years. During that time only mechanical harvesting has been used to reduce impacts from weeds such as Eurasian watermilfoil, curlyleaf pondweed and hornwort. This approach creates viable non-native plant propagules that disperse into Lake Tahoe and further threaten near shore habitats. To improve management and reduce threats to Lake Tahoe, the Tahoe Keys Property Owners Association (TKPOA) engaged both the scientific community and concerned public-agency, regulatory and private stakeholders in a process to develop a plan that incorporates all feasible and current aquatic weed control technologies and monitoring methods. The environmental sensitivity and uniqueness of Lake Tahoe required a fully transparent and proactive approach aimed at minimizing non-target effects while achieving identified goals. The greatest challenge has been integrating the use of registered aquatic herbicides into the plan due to specific prohibitions against introducing chemical constituents into Lake Tahoe. Through a series of public meetings, continuous informational outreach and crucial changes in the regulatory policy, there is now an opportunity to greatly improve efficacy, decrease propagule pressure and an eventually lower annual costs of management. The overall process in attaining consilience in the midst of disparate perspectives about risks and benefits associated with proposed "solutions" has led to a heightened awareness of lake ecosystem services, invasive species threats and what are practical components of an integrated management plan.

NOTES

Optimization of Chlorination Strategies for Dreissenid Mussel Control

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[1]*Ontario Power Generation*
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[3]*RNT Consulting*

Zebra and quagga mussels have been in the Great Lakes since the late 1980s. Most of the chlorination strategies for industry were developed during that time and in most cases have not been changed since.

In this presentation we will review the basis for the start and end of chlorination treatments on the Great Lakes, drawing on recent mussel settlement studies carried out in Lake Ontario and Lake Huron. Further we will discuss chlorination trials carried out on mixed populations of quagga and zebra mussels under three different temperature regimes.

This study was sponsored by the Candu Owners Group under contract SOR#305NE

NOTES

Developing a Treatment Method to Protect Alberta's Irrigation Pipelines from Invasive Dreissenid Mussels

Nicole Seitz Vermeer, *Lloyd Healy and Ki Au*
Alberta Agriculture and Forestry

Alberta is home to a world-class irrigation industry. Within 13 irrigation districts, approximately 8000 km of canals and pipelines, worth an estimated $3.5 billion, distribute water to 572 000 ha of irrigated land, 32 000 ha of wetlands, several communities, recreation areas, industrial users, and thousands of rural residents. Irrigation is supplied by approximately 50 storage reservoirs, several of which are also used for recreational boating and angling, putting them at risk of an introduction of invasive mussels from trailered watercraft. This would prove to be highly challenging for water management, particularly for irrigation, in that pipelines could become clogged, or fouled, resulting in reduced water conveyance and increased maintenance costs. The Government of Alberta recognizes that a detection of invasive mussels in an irrigation reservoir will require immediate action. Treatment of water in irrigation pipelines must be carefully considered, and any pipeline treatment must be done separately from the affected reservoir. There are however, several challenges associated with pipeline treatment including limited control options, the unique nature of Alberta's irrigation conveyance systems, and meeting the needs of water users. In partnership with Alberta's irrigation districts, Alberta Agriculture and Forestry is exploring these challenges in several ways, including product registration for invasive mussel control in surface water, and logistics for pipeline treatment. Current research efforts are focusing on treating irrigation pipelines with potash due to its success at killing mussels in other jurisdictions. Research will also be done to understand how to maintain a steady concentration with fluctuating water volumes to ensure a lethal dose is reached while simultaneously supplying water to crops. Environmental fate and transport of potash must also be considered. Such a proactive approach will ensure that the necessary tools and processes are developed and can be used if dreissenid mussels invade southern Alberta's irrigation systems.

NOTES

Mortality Responses of Quagga Mussels to KCl Solutions Prepared in Different Source Waters

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[2]*KASF Consulting*

Rapid responses to field infestations of zebra mussels in the US and Canada have been addressed at several locations using treatments of muriate of potash (KCl) introduced into contained areas of lakes or reservoirs. The most successful of these treatments was conducted at Millbrook Quarry, Virginia, where a target concentration of 100 mg/L, was applied. The concentration was selected to provide low to no risk to non-molluscan aquatic species, vegetation, or human exposure. Although this low dose eradication has been proposed as a preferred rapid response protocol to kill infestations of Dressinid mussels, few if any controlled studies have tested this tool as effective on quagga mussels. Moreover, limited information has been provided to relate responses observed to metrics of water quality. We compared the response of quagga mussel adults to two concentrations of KCl (100 and 200 mg/L) prepared in water obtained from the Colorado River, Arizona, and the Snake River, Idaho. In additional studies, we compared the mortality of quagga mussel veligers exposed to 960 mg/L prepared in the same water sources, and one additional source of groundwater from Idaho. We found highly variable results depending on the water source. Quagga veligers tested in Colorado River water showed little to no mortality up to 24 h exposure in 960 mg/L KCl, but mortality occurred within 8 h of exposure to water from the Snake River. Adult quagga mussels showed 100% mortality within 10 days of exposure to 200 mg/L KCl, regardless of water source. Our characterization of the water sources included examining a suite of metals by ICP, measurements of salinity, conductivity, TDS, and pH. We conclude that rapid response protocols must consider components of water quality in addition to water temperatures, to assure that the concentrations of KCl to be applied will be effective.

NOTES

Control of Dreissenid Mussels with a More Rational Use of Copper

David Hammond
Earth Science Labs, Inc.

Since the time zebra and quagga mussels were introduced to North America in the mid-1980s they have had profound impacts on native species and the aquatic environment in general. They have also caused tremendous economic damage by fouling infrastructure such as pipelines, intakes, screens, pumps, cooling systems and other systems. Managers and maintenance crews in many areas have responded by using various forms of chlorine and/or permanganate to discourage infestation, despite the fact that neither chemical is specifically labeled for this purpose and each has significant drawbacks. In 2013 a liquid formulation of copper ions was approved by the EPA for control of Dreissenids in lakes and open waters, and subsequently the label was expanded to include pipelines and flowing waters, making it the only product that is both NSF-certified for drinking water and legally labeled as a Molluscicide. Dose-response data from municipal WTPs that have adopted use of liquid copper ions to control zebras and quaggas will be presented.

NOTES

Quest for Durable Foul-Release Coatings

***Bobbi Jo Merten**, David Tordonato, Allen Skaja*
Bureau of Reclamation

Coatings research is part of an ongoing interdisciplinary program being conducted by the Bureau of Reclamation to reduce invasive mussel impacts to hydraulic structures. In May 2008, a program was initiated to evaluate the efficacy of commercially available technologies in preventing mussel attachment to underwater infrastructure. All materials were field evaluated at Parker Dam on the lower Colorado River where quagga mussel colonization is extensive.

Initial screening showed silicone foul-release coatings prevent mussel attachment for at least several years at Parker Dam. Eventually Reclamation evaluated a hard silicone-epoxy-hybrid foul-release coatings that had very low attachment strengths. Scale-up projects were conducted on fish screens and trashracks for these materials. The scale-up of fish screens equipped with brush cleaning equipment showed soft foul-release coatings damage easily, while the hard foul release coating was resistant to the constant abrasion from the nylon brushes. Conversely, a trashrack section equipped with a trash rake cleaning equipment had more damage on the hard foul-release coating compared to the soft foul-release coatings.

This paper provides scale-up testing results and discusses the implications thereof. In addition, updated screening results for new foul-release technologies are included. Coatings that are more durable continue to be sought, such as those with good abrasion resistance and low mussel attachment forces. In addition, Reclamation has evaluated silicone-based materials not designed for fouling prevention (gaskets, caulks, and ice-phobic coatings), are also resistant to mussel attachment.

NOTES

Ecological Impact of Ponto-Caspian Invertebrates and Fish in a Shipping Canal Ecosystem

Alain De Vocht *and Sarah Descamps*
PXL Bio-Research – CMK, University Hasselt

The largest canal in Belgium is invaded by different Ponto-Caspian invertebrate and fish species. The five most abundant invertebrate species in the canal are Ponto-Caspian and the benthic fish community is dominated by round goby (*Neogobius melanostomus*). Interaction between the killer shrimp (*Dikerogammarus villosu*s) and the native common freshwater shrimp (*Gammarus pulex*) are investigated in the lab as well as the food preference of round goby. Interspecific competition between the native fish species roach (*Rutilus rutilus*) and round goby are tested.

Round goby predates more often on the common freshwater shrimp rather than the killer shrimp mainly because the differences in behaviour between both prey species. Regardless the shrimp species, larger prey items are selected. Competition experiments between the killer shrimp and the common freshwater shrimp shows a difference in choice of shelter. Where the killer shrimp selects *Dreissena*-shells and is found in the lower water layer, the common freshwater shrimp is found between plants and more often in the higher water layer of the test container. Predation of killer shrimp on common freshwater shrimp was recorded as well. The difference in habitat results in a higher predation of the common freshwater shrimp in comparison to killer shrimp.

In competition experiments, round goby consumes significantly more freshwater shrimps than roach. In combination with the interspecific aggressive behavior of round goby towards the native roach, round goby has an important competitive advantage on roach in shipping canals and important angling waters.

Both the presence of invasive killer shrimp and round goby results in the overall absence of the native common freshwater shrimp in Belgian canals. Round goby is found to be a better competitor for benthic food in comparison to native roach, severely impacting the native invertebrate and fish communities in artificial water bodies in Belgium or Europe.

NOTES

No Significant Negative Impact on Native Fish Species during First Years of Colonization by Ponto-Caspian Gobies

***Hugo Verreycken**, Hans Van Calster, Luc De Bruyn and Tim Adriaens*
Research Institute for Nature and Forest

Ponto-Caspian gobies have invaded most of Europe with the most recent invasion in the western part. Since 2010, tubenose goby *Proterorhinus semilunaris*, round goby *Neogobius melanostomus* and bighead goby Ponticola kessleri (since 2012) are spreading fast in Belgium. The invasive populations of these three species are closely monitored in order to study their distribution, population density and also their impact on native fish species. Here we present the results of a 4 year monitoring programme of the fish populations in the Meuse basin in Flanders (North Belgium). The Meuse constitutes the border between Flanders and the Netherlands and the main river bed and its tributaries harbour many rheophilic species that are rare or absent in the rest of the Flemish waterways e.g. river and brook bullhead *Cottus perifretum* and *C. rhenanus*. As the river bottom of the Meuse is constituted of small and big boulders and the banks often are strengthened by rip rap, the river acts as an ideal habitat for benthic native fish species but also provides the three benthic invasive gobies with a perfect surrounding for a rapid invasion. The Flemish part of the Meuse was first colonized by tubenose goby, followed by bighead and round goby in 2013. Especially the latter species proliferated in 2014 – 2015. Despite the rapid colonization of the Meuse, no significant impact of these gobies on native fish species could be proven during our four year monitoring programme. This is probably due to the yet short invasion time in the Meuse. Continued efforts in the following years can maybe confirm the findings of Dutch colleagues: the Ponto-Caspian invasion started earlier in the Dutch part of the Meuse and evidence was found of a sharp decline in the river bullhead as a result of the colonization by round goby.

NOTES

Evaluating and Predicting Impacts of Globally-invasive Freshwater Fishes Using Multi-population Comparisons

Suncica Avlijas[1], *Nicholas E. Mandrak*[2], *Anthony Ricciardi*[1]
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Risk assessment of invasive species is challenged by context-dependent variation in impact across recipient sites. Globally-introduced freshwater fishes are valuable model species to investigate environmental factors that mediate this variation. One such species, the Tench (*Tinca tinca*) is a benthic Eurasian cyprinid that has been introduced worldwide. In spite of its broad distribution and extensive government stocking efforts, there is a paucity of information concerning its ecological impacts. To address this gap, we are collecting field data on Tench populations across disparate invaded watersheds in North America and Africa. Ecological impacts are being assessed through an analysis of diet overlap of Tench with fishes in invaded communities and changes in the composition of those communities following Tench introduction.

With the goal of improving our capacity for rapid risk assessment, we will test the predictive ability of morphometric (shape space) analysis - a novel method of explaining and forecasting community-level impact of introduced fishes. Shape space – a proxy for niche space – will be calculated using morphometric data obtained from photographs, for four invaders (Tench, Carp, Largemouth Bass and Smallmouth Bass) and all co-occurring fishes in three South African watersheds. Data on impacts of these invaders across sites (inferred from historical changes in the presence or abundance of native species) will be correlated with the relative size and position of the shape space they occupy at each site. We will test two contrasting predictions: 1) Invaders whose shape space overlaps with natives in the region will have higher impacts (competition hypothesis); or alternatively, 2) invaders that occupy distinct shape space have higher overall impacts owing to their novel use of resources and the naiveté of the recipient community (ecological distinctiveness hypothesis).

NOTES

Food Competition as a Mode of Impact in a Riverine Round Goby Invasion

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In the Laurentian Great Lakes, the Round Goby is rapidly expanding its range and dominates fish communities in many littoral and benthic habitats. Its ecological impact has been extensively investigated in the Great Lakes proper; however, less is known about its impact in tributaries. We surveyed the Grand River (Ontario) as a model system to assess Round Goby impact on native benthic fishes in a flow-modified tributary. Sequential lowhead dams separate proximate uninvaded and invaded river reaches, and create upstream gradients of increasing water velocity. On invaded reaches, Round Goby abundance exponentially declines with increasing water velocity, whereas native benthic fishes are at their lowest abundance at sites of low water velocity and high goby abundance – a trend not seen on uninvaded reaches. These observations suggest competitive exclusion of native fishes. To assess competition for food as a potential mechanism of exclusion, we examine diet overlap and isotopic niche breadth in Round Goby and two native darters. Niche overlap would indicate impacts are likely to occur when Round Goby establish upstream of lowhead dams. Comparison of niche breadth and trophic position values for Round Goby in tributaries with those reported in the Great Lakes proper may also determine if diet specialization is occurring in these newly invaded systems.

NOTES

Diet Spectrum and Preference of the Invasive Round Goby (*Neogobius melanostomus*) in Flanders (North Belgium)

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The non-native Ponto-Caspian round goby (*Neogobius melanostomus*) has recently become invasive and now spreads rapidly in Western Europe. Round goby was first recorded in Flanders (Belgium) in 2010 and is now widely distributed over the big rivers and canals. One of the attributes that can explain the success of round goby is the plasticity in diet choice. We analyzed stomach contents of fish caught in four water systems in Flanders (i.e. tidal river, gravel pit and two canals). Fish from different locations showed significant differences in their diet composition. At the river Scheldt and the Albert canal, diet composition was dominated by one group (Caridea and Dressenidae respectively). The diet in the gravel pit consisted of equal portions of Gammaridae, Chironomidae and Dressenidae, while in the Moervaart canal Mollusca (Bithyniidae, Sphaeriidae and Dreissenidae) and Chironomidae were the main food source. Diet composition also differed among sexes, seasons and size classes. Larger specimens contain more Dreissenidae while smaller fish contain more Gammaridae and Sphaeriidae. An aquarium food choice experiment revealed that when the fish can choose between Dreissenidae en Gammaridae they show a clear preference towards Gammaridae, regardless of their original habitat.

NOTES

Benefits Derived in Louisiana from the Long Term Management and Control of Waterhyacinth (*Eichhornia crassipes*)

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Waterhyacinth is a floating aquatic plant native to the Amazon basin in South America. Outside of its native range, it can display aggressive growth and spread forming large impenetrable mats. It is widely considered one of the worst nuisance plants in the world. In Louisiana, state-wide spring and fall waterhyacinth surface acreage and management cost data was available for over 40 years. The benefits of management were analyzed by examining growth potential as the difference in spring and fall acreage over time and changes in distribution under management. These were compared to projected distribution and seasonal growth under an alternate no-management scenario. Differences were used to analyze treatment effectiveness in terms of reducing plant density and surface coverage, and effects on human uses and values. A main objective of the analysis was to estimate monetary values for changes in ecosystem benefits. However, if important benefits could not be monetized, we attempted to quantify with non-monetary benefit indicators. Significant monetary and non-monetary benefits were identified from continued management of this invasive weed over the last 40 years.

NOTES

Growth of *Elodea canadensis* (in Swedish lakes): A Head Start for an Invasive Species in Strongly Seasonal Environment

Kristina Tattersdill[1], *Frauke Ecke*[1], *André Frainer*[1,2], *Brendan G. McKie*[1]
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Invasive macrophytes can attain very high biomass in lakes, with potential consequences for biodiversity and ecosystem functioning. Our focus has been on Canadian waterweed (*Elodea canadensis*), a long-established invasive marcophyte in Sweden, and its effect on lake ecosystem services. To understand its impact one needs to understand the plant's dynamics. As one research component, we have conducted a pot experiment over 9 months (from late summer to Spring) to establish a growth pattern for the invasive plant through less studied periods of the year. We observed a general pattern of late summer-autumn growth, winter dieback (but not to zero biomass) and spring regrowth. Sampling in late March further identified growth initiated at water temperature of 4°C. We discuss the relative importance of abiotic environmental parameters (water chemistry, sediment characteristics) compared with ambient macrophyte density and composition for growth of Elodea canadensis. We further look at the implications this has for the diversity and composition of macroinvertebrate and macrophyte community.

NOTES

Vegetative Reproductive Capacity of Crested Floatingheart (*Nymphoides cristata*)

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Crested floatingheart is an attractive floating-leaved plant that is used extensively as an ornamental in water gardens. It is hardy to USDA Zone 7 and can tolerate temperatures as low as 1 °F (-17 °C). It escaped cultivation and has invaded bodies of water in several states in the US, including Florida and South Carolina. Little is known regarding seed production in the species, but crested floatingheart seems to reproduce primarily by vegetative means via rhizome clusters ("ramets") that are borne in leaf axils. Our goal was to determine the effects of substrate composition and nutrient level on ramet production. Single well-rooted plants that were 35 to 45 cm with 4 to 6 leaves were planted in in 6L dishpans filled with one of five substrates (ranging from 100% sand to 100% peat) and one of four nutrient levels (ranging from 0 to 4 g of fertilizer per L of substrate). All plants were cultured for 6 months after planting (MSP); four replicates of each factorial combination were prepared and these experiments were repeated four times. Analyses of variance revealed that substrate had a minor effect on ramet production but this was transient and no longer significant by 2 MAP. In contrast, nutrient level had a profound effect on ramet production and plants fertilized at the 4 g/L rate produced an average of > 450 ramets by 6 MAP. These results show that crested floatingheart has great capacity to reproduce by vegetative means, particularly under high-nutrient conditions, and that early detection and rapid response is critical to prevent this beautiful but invasive plant from overtaking aquatic systems.

NOTES

Ornamentals Behaving Badly

Nicole Kimmel
Alberta Agriculture & Forestry

Horticulture industry has long been a high suspect in invasive plant invasions. And with good reason, this market is supported almost solely by introducing large numbers of non-native plant species into new areas. Most species have little information available on which have the potential to become casual escapes, unless they are notorious for escaping. The number and/or frequency of plants released at introduction, known as propagule pressure, are emerging as an important factor of invasion success. The scariest prospect for any invasive plant manager is to have a popular plant in horticulture, with rapid distribution, that has a large potential for escape.

The demand for horticultural plants is driven by consumers in search of a "good garden plant" whose attributes often allow them to become invasive. The horticultural industry seeks to meet consumer demand by importing or breeding plants with these matched attributes. Ornamental escapes have had negative environmental, economical, recreational, & public health impacts. Billions of dollars are spent on these escapes nationally every year, so why do we continuously allow ornamentals in with little to no scrutiny. There are thousands of escaped plants species in Canada, many started as ornamentals.

In Alberta alone, approximately half of the regulated weed list originated as ornamental species. I will highlight some aquatic plant problems now occurring in Alberta, because of misbehaved ornamentals. Species highlighted will include Flowering Rush (*Butomus umbellatus*), Himalayan Balsam (*Impatiens glandulifera*), Pale Yellow Iris (*Iris pseudacorus*), Purple Loosestrife (*Lythrum salicaria*) and Knotweed (*Reynoutria spp*) species.

NOTES

Mapping Watershed Degree of Invasion Across the Continental United States

Amy J. Davis *and John A. Darling*
U.S. Environmental Protection Agency, National Exposure Research Laboratory

Exotic aquatic plant invasions trigger a cascade of negative effects, resulting in altered structure and function of freshwater ecosystems, loss of native biodiversity, and reduction of valuable ecosystem services such as recreation and water quality. The problem of biological invasions is well known, and as a result there are multiple web accessible digital repositories that provide geo-referenced species occurrence data to enable the analysis of the spread and impact of invasive species. However, these tools are currently limited to single species distribution maps and do not provide a way to evaluate how exotic species richness (the number of unique exotic species) varies by watershed, thereby preventing us from identifying the hotspots of aquatic species invasions, and their drivers and impacts across the U.S. To address this, we have integrated occurrence and other attribute data for a suite of known aquatic invasive species from all reliable sources into a single geospatial database that can be queried to summarize exotic aquatic species richness by hydrologic unit (HUC) for the continental United States. We will present this data layer and illustrate how it can be used to test hypotheses regarding the broad scale drivers of freshwater aquatic species invasions.

NOTES

Evaluating Copper Ion Generator for Control of Quagga Mussels

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Dreissenid mussels, zebra and quagga, arrived in the United States from Europe in the 1980s and quickly spread to many Eastern waterways, rivers, and lakes. In 2007, dreissenid mussels crossed the continental divide and invaded the lower Colorado River, Arizona and Nevada. Through aqueducts they spread to Southern California and Texas. Mussel populations have exploded in many of these western locations.

The toxicity of copper to aquatic life has been recognized for centuries. Ocean going sailing vessel hulls were frequently covered by sheets of copper to minimize hull fouling by marine organisms. Mollusks are particularly sensitive to the presence of copper in the environment. The use of copper ion generator technology for the control of invasive mussels has been promoted for over 20 years. Blume et al. (1994) conducted a series of experiments to determine if the copper ion technology could be used against zebra mussels. They concluded that a continuous dose of 10 ppb of copper ion would decrease veliger settlement in the system to be protected and they speculated that adults already present in the system treated would be eliminated by the long term exposure to low levels of copper ions.

Bureau of Reclamation sponsored an independent evaluation of the copper ion generator technology in a flow through system using veliger rich water from the Colorado River and adult mussels collected from Lake Mohave. In this presentation we will present data on the effects of various levels of copper generated by the copper ion generator on the settlement of larval quagga mussels (veligers) and the effects of the tested copper level on captive adult quagga mussels. The overall performance of the copper ion generator itself such as, ease of use and reliability was also tested and will be discussed.

NOTES

Invertebrate Community Response to Zequanox® in Aquatic Mesocosms

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Zequanox® is an emerging biopesticide for Dreissenid mussel control, and may be widely used to control zebra and quagga mussel infestations in natural and human-made waterways. Previous research has shown that Zequanox® is highly effective and specific (Molloy *et al.* 2013; Meehan *et. al.* 2014), but has yet to characterize non-target effects at a community scale. We carried out a 43-day experiment in aquatic mesocosms to determine the potential direct and indirect community-level responses (effects and recovery) of zooplankton, macroinvertebrates, and algae to manufacturer-prescribed Zequanox® treatment at 100 mg/L (a.i.). Results of this study will be discussed.

NOTES

Developments in Bio-based Management of Juvenile and Larval Stage Zebra and Quagga Mussels in Industry and Natural Resource Management

Carolyn Link *and Megan M. Weber*
Marrone Bio Innovations

New zebra and quagga mussel infestations (*Dreissena polymorpha* and *Dreissena bugensis*) are discovered across North America each year. These damaging invaders cause significant economic harm by occluding industrial raw water systems, clogging boat motors, and creating recreational hazards due to sharp shells. The mussels also cause ecological harm by altering nutrient dynamics in food webs, promoting harmful algal blooms (HABs), and colonizing native mussels. Zequanox®, a biopesticide made from the dead cells of the common soil bacterium *Pseudomonas fluorescens* strain CL145A, provides a tool for both industry and natural resource management to combat invasive mussel colonization.

Since 2012, Zequanox has been used in industrial settings in the United States and Canada, and was recently registered in the United States for open water uses in 2014. This presentation will focus on new developments targeting control of early life stages (juveniles and veligers). Using more frequent, but shorter duration, low-concentration exposures in industrial settings requires much less product over the course of a year than annual treatments by targeting the juvenile life-stage throughout the settlement season. This type of treatment has the added benefit of mitigating issues of shell debris by minimizing new settlement and the growth of mussels beyond 4 mm. In the area of natural resource management, treatments have demonstrated that Zequanox can be used against the veliger life-stage, providing opportunities to reduce the spread of invasive mussels in fish transport water for aquaculture, game fish stocking, bait fish, native mussel relocation projects, and other activities where water containing veligers is transported.

NOTES

The Ins and Outs of Registering a New Product for the Control of Aquatic Invasive Species

John F. Fournier
Acadia Regulatory Consulting, LLC

The spread of Dreissenid mussels across North America has continued for most of the last three decades. There are many reports on their devastating effects on ecosystems while industries and municipalities have spent billions of dollars trying to mitigate their effects on municipal infrastructure, water conveyance structures and industrial cooling systems. Industry and conservation groups continue to meet to discuss the latest research on Dreissenids and to develop "rapid response" plans in areas yet to be impacted.

All plans for response, without approved mitigation tools, are for naught. Despite the recent innovations and studies into non-chemical means of control, chemical methods are likely to always be essential to ensure uninterrupted operation of municipal water treatment systems, power generation facilities, and more.

Molluscicides are a challenge to register at the federal, state, and provincial levels by pesticide regulatory agencies because of their intended use patterns. Unlike other pesticides, they are not generally applied to farm agro-ecosystems (low inherent biodiversity), they are frequently applied directly to very diverse, natural, and sensitive aquatic ecosystems. Regulators balance risk/hazard against "value" when making registration decisions. When registering crop protection materials, the "value" is obvious since we need these crops to feed the human population. Demonstrating the value of molluscicides, by comparision, is not an easy thing to do since many industries have never carefully quantified the costs of mollusk impacts and, as a society, we still fail to assign economic value to ecosystems or ecosystem services.

In addition, unlike other pesticide products (subject only to FIFRA/PCPA), molluscicides are also subject to regulation under Clean Water legislation – subjecting their use to an additional, very challenging set of requirements. In the US, each and every treatment that will result in a discharge to a waterway requires permitting under the NPDES system or a state "Pesticide General Permit" approval system. In Canada, Environmental Compliance Approvals (ECAs) are required.

This presentation will discuss chemical molluscicides which enjoy a "grandfathered" status, new chemical control methods and why they are difficult to register and registration of "control devices". It will also be a plea for coordination of all stakeholders in the battle against dreissenids.

NOTES

Use of a Differential Simple Stain to Confirm Mortality of Dreissenid Mussels in Field Research Experiments

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In previous toxicological studies on veligers of Dreissenid mussels, accurate and rapid determination of mortality or survival has been a challenge. Current recommended methods for observing mortality or survival of treated Dreissenid mussel veligers is to observe each individual for long periods of time to identify internal movement or other signs of life. This procedure is complicated by post-mortem infestation of tissues with decomposers. When using this procedure to determine the toxic effect of potassium on veligers, researchers found that veligers look dead with shells agape and vellum exposed with no movement. However, after a recovery period in potassium free water, the test subjects were alive and swimming.

The use of Fast Green stain has been commonly used for food coloring, tissue staining, and more recently staining saltwater mussel spat and freshwater Dreissenid larval and juvenile life stages. Fast Green is a differential simple stain that only dyes dead tissue. This allows for easy and accurate determination of living or dead veligers and highlights empty shells which otherwise are mistaken for a living individual. In a study testing the toxicity of potassium chloride to Dreissenid veligers, the Fast Green stain method was used to differentiate live, dead, and empty shelled individuals to build toxicity curves and to determine the endpoints with a high degree of confidence.

The Fast Green stain method is easy to use in the field or laboratory setting and does no harm to the test subjects or other zooplankton species. This method also allows for easier identification of the Dreissenid veligers in the plankton. We conclude that the use of this method is essential to quickly and accurately determine mortality of veligers in any toxicity experiment, where 100% mortality and high confidence in the results are important such as in eradication efforts within water transfer applications.

NOTES

Towards Selective Removal of Invasive Fishes and Passage of Native Fishes in Rivers

Rob McLaughlin[1], *Andrew Muir*[2], *Tom Pratt*[3], *John Dettmers*[2]
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In many jurisdictions, in-stream barriers are used to restrict the spread and reproduction of invasive fishes, but these barriers can also limit the migratory movements of native fishes. This creates potential conflict between management objectives of protecting native fish communities through control of invasive species and of enhancing the production and diversity of native fishes through increased connectivity. In the Laurentian Great Lakes, barriers are an important management tool in the control of invasive sea lampreys (*Petromyzon marinus*). Sea lampreys remain highly destructive in the Great Lakes and continue to threaten a 7 billion dollar fishery. Developing selective, effective bi-directional fish passage to remove sea lampreys, while allowing the passage of native fishes, has become an issue of great importance for Great Lakes fisheries managers. To date, selective passage efforts have included a variety of approaches, including velocity barriers, seasonal barriers, trap-and-sort fishways, and eel ladders. The integration of emerging technologies, such as push-pull and electrical and pheromone guidance, as well as advances in engineering, such as eel-style ladder traps, are providing hope that selective, bi-directional fish passage solutions are possible. The Great Lakes Fishery Commission is developing a research theme specific to selective bi-directional fish passage to address the conflict between invasive species control and aquatic fragmentation.

NOTES

Ecology and Control of Invasive Northern Pike in the Columbia River, Canada

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[4]*Teck Metals Inc.*
[5]*Mountain Water Research*

Illegal introductions of Northern Pike (NP) (*Esox lucius*) into the U.S. section of the Pend D'Oreille River has led to colonization of the Lower Columbia River (LCR) in Canada downstream of the Hugh L. Keenleyside Dam. Pike predation is threatening native fish populations and potentially impacting recovery efforts of SARA listed species including White Sturgeon.

Over the past two years the total number of pike removed from the study area was 288 through gill-netting and angler incentive programs. A Lincoln-Petersen mark-recapture estimate conducted in 2015 using PIT tags estimated the population in the Robson Reach area to be 410, indicating that approximately 30% of the population was removed. The lengths and weights of captured NP were 15% and 33% lower respectively in 2015 than in 2014, suggesting the majority of large adults have been removed and a new age class is being captured. Our results indicate the current gill-netting effort is impacting the pike population in the LCR and continues to be a viable control option.

Approximately 37% of pike caught in 2015 contained food. The diet of those fish comprised 55% native salmonid species (Rainbow Trout, Kokanee and Mountain Whitefish), but no SARA listed species.

Because we have not been able to detect any pike spawning areas in the Canadian stretch of the Columbia or Pend D'Oreille Rivers, we plan on catching and tracking 15 pre-spawn female NP tagged with acoustic transmitters in the spring of 2016 to locate spawning habitat. We are examining the geographical life history of NP in the LCR by microchemical analysis of otoliths, to compare unique chemical signatures within the otolith matrix and water samples from different locations in the Lower Columbia. We also aim to determine the efficacy and limitations of using environmental DNA from water samples as a detection method for Northern Pike.

NOTES

Invasion Genetics of the Eurasian Round Goby in North America: Patterns Across Time and Space

Matthew R. Snyder *and Carol A. Stepien*

University of Toledo, Lake Erie Center and Department of Environmental Sciences, Great Lakes Genetics/Genomics Laboratory

Biological invasions comprise accidental evolutionary experiments, with their genetic compositions believed to govern relative success and persistence. However, little is known about whether and how their genetic patterns change temporally and/or spatially in relation to the founding source. One might predict that most invasions would experience a founder effect, have little genetic differentiation across the new range, and gain variation over time with new arriving propagules. To test these predictions, we analyze population genetic diversity and divergence patterns of the Eurasian round goby *Neogobius melanostomus* across the two decades of its North American invasion, comparing results from 13 nuclear DNA microsatellite loci and mitochondrial DNA cytochrome *b* sequences. Hypotheses tested include genetic stasis, genetic replacement, and/or genetic supplement, evaluated at the invasion core and expansion sites in the Laurentian Great Lakes, as well as their Dnieper River, Black Sea source. Results reveal pronounced genetic divergence among populations, which each remaining relatively consistent in genetic composition over two decades, supporting the genetic stasis and founder takes most hypotheses. It is likely that some genetic resistance occurred after populations became established and grew appreciably in numbers, crowding out later arriving genotypes. The original invasion core stayed the most similar to the native source. Secondary expansion sites all remained distinctive, yet experienced some allelic composition convergence towards the core population over time, attributable to slight genetic supplementation and/or drift. Such complete geographic and temporal coverage offers rare insights into invasion genetics, which is discussed in relation to a wide range of exotic taxa.

NOTES

Genetic Patterns of the Invasive Eurasian Ruffe over Time and Space: Comparing Introductions in the Laurentian Great Lakes versus England

***Devon J. Eddins**, Nathan T. Marshall, Matthew R. Snyder and Carol A. Stepien*

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Invasive species are a leading cause of worldwide biodiversity decline, with the Laurentian Great Lakes experiencing some 186 introductions. In ~1986 the Eurasian ruffe (*Gymnocephalus cernua*), a percid fish, was discovered in St. Louis Harbor, Lake Superior; about this time it also invaded Bassenthwaite Lake in northern England. The former was attributed to ballast water discharge from one or more transoceanic vessel(s) arriving from the Baltic Sea region (according to our prior genetic data), while the latter was an apparent bait bucket introduction from southern England. The present investigation aimed to: (1) determine differentiation and diversity patterns between the invasive versus native ruffe populations, and (2) analyze whether their genetic compositions have changed over time, using 10 nuclear DNA microsatellite loci. Results indicate: (1) pronounced differentiation among the two invasive populations, with the native Baltic Sea and Great Lakes populations being similar and Bassenthwaite Lake being very different (2) both invasions likely were large introductions from different founding sources, with just slight founder effects, (3) their genetic compositions have remained consistent over time (early 1990s-present), and (4) there is great genetic similarity across the current Great Lakes distribution, indicating range expansion of the initial colonists, without additional introductions. Native populations in the Baltic Sea region slightly differed (Vistula Lagoon versus Elbe River), with the latter genetically closest to the Great Lakes, indicating a likely founding source. This study demonstrates that population genetic analyses provide a robust and informative approach for discerning the spatial and temporal patterns of invasions.

NOTES

A Decade of Gene Diversification of Viral Hemorrhagic Septicemia (VHS) Since its First Appearance in the Laurentian Great Lakes

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Viral Hemorrhagic Septicemia virus (VHSv) causes one of the world's most serious fish diseases, infecting >80 freshwater and marine species. A new, novel, and especially virulent substrain –VHSv-IVb– first appeared in the Laurentian Great Lakes about a decade ago, resulting in massive fish kills. It rapidly spread and has genetically diversified. This study analyzes its mutational patterns across the Great Lakes for the novel non-virion (*Nv*) gene that is unique to this group of novirhabdoviruses, in relation to its glycoprotein (*G*), phosphoprotein (*P*), and matrix (*M*) genes. Results show that the Nv-gene has been evolving the fastest (k=2.0x10^{-3} substitutions/site/year), with the G-gene at ~1/7 that rate (k=2.8x10^{-4}). Most (all but one) of the 12 unique *Nv*- haplotypes identified encoded different amino acids (26 changes). Among the 12 corresponding *G*-gene haplotypes, seven vary in amino acids (eight changes). The *P*- and *M*- genes are more evolutionarily conserved, evolving at just ~1/15 (k=1.2x10^{-4}) of the *Nv*-gene's rate. The 12 isolates contained four *P*-gene haplotypes with two amino acid changes, and six *M*-gene haplotypes with three. Patterns of evolutionary changes coincided among the genes for some of the isolates, but appear independent in others. New viral variants were discovered following the large 2006 outbreak; such differentiation may have been in response to fish populations developing resistance. Two 2012 variants were isolated by us from central Lake Erie fish that lacked classic VHSv symptoms, having genetically distinctive *Nv-, G-,* and *M*-gene sequences (with one of them also differing in its *P*-gene); they differed by a *G*-gene amino acid change and also diverged from all other isolates by a shared *Nv*-gene amino acid change. Such rapid evolutionary differentiation may allow new viral variants to evade fish host recognition and immune responses, facilitating long-time persistence along with expansion to new geographic areas.

NOTES

Determining a Best-case Effectiveness of a Molecular Method for the Detection of Aquatic Invasives

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Next-generation sequencing and clustering pipelines have several applications, including obtaining biodiversity estimates and the early detection of non-native species. One can obtain an eDNA sample from an aquatic source and monitor for invaders by performing sequencing, clustering, and BLAST. Such an approach allows improved detection of cryptic and rare taxa, and can provide early warning for an invasion. Though next-generation sequencing is very sensitive, it is difficult to distinguish representatives of rare species and artefacts. This is especially significant early in an invasion, where invaders are of low abundance. Performing either type I or type II errors can hurt the integrity of results and have severe consequences in the early detection of invasive species. However, common clustering and BLAST pipelines provide several options to reduce the abundance and impact of errors. These options and their parameters can be arranged in many combinations. For any data set, some combinations may yield some errors, and some combinations may yield optimal results (correctly recovering all taxa in a sample, while minimizing erroneous and redundant operational taxonomic units). Unfortunately, in reality, optimal parameter sets for these pipelines cannot be known a priori by one employing the pipeline. Using sequences of known origin, we search for optimal parameter sets for use in a clustering and BLAST pipeline that employs common programs (UPARSE and BLASTn). We intend to aid users of this pipeline, particularly in application to molecular identification of aquatic invasive species using eDNA. We found optimal parameter sets retain longer sequences and perform little or no filtering. Using optimal parameter sets, we aim to determine best-case sensitivity of this pipeline using real datasets. We hypothesize that the sensitivity of this pipeline is highly dependent on the taxa (native and non-native) present and less sensitive than previously thought.

NOTES

Early Detection Monitoring for Non-native Fishes and Invertebrates in Lakes Erie and Michigan

Stephen R. Hensler[1], *Timothy R. Strakosh*[1], *Anjanette Bowen*[1], *Eric Stadig*[2], *Chris Olds*[1], *Sandra Keppner*[1], *Dan Drake*[1], *Robert Haltner*[1], *Heidi Himes*[1]

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In response to decades of invasions by non-native species, the U.S. Fish & Wildlife Service (USFWS) has developed and is implementing an early detection monitoring program for non-native aquatic fishes and select invertebrates in the Laurentian Great Lakes. The goal of this program is to detect species while they are still rare enough that eradication efforts may be initiated and vectors addressed in time to stop new invasions from occurring. Collections began in the Great Lakes and their connecting waters in 2013, and the current focus is to achieve a 95% detection rate for species present in Great Lakes areas where new non-native species are likely to first appear. Using risk assessments to inform sample site and gear selection, probabilistic study design to choose specific sampling locations to be examined both spatially and temporally, rarefaction to estimate species detection probability, molecular techniques to improve organism detection and identification, and valuable collaboration with partner agencies and institutions, the USFWS early detection monitoring program is designed to be flexible and responsive to invasive species challenges in a changing world.

NOTES

The Development and Validation of a LAMP Assay and Portable Instrument to Rapidly Detect Invasive Species in Transport as Bait

Christopher M. Merkes, *Craig A. Jackson and Jon J. Amberg*
U.S. Geolgical Survey

Aquatic invasive species are a significant problem throughout the world. They cause millions of dollars in damages to industry, devastate natural ecosystems, and ruin outdoor recreational areas. Preventing their spread is imperative to preserving our natural resources. One potential pathway invasive fishes can spread is by harvesting and transporting baitfish. Often shipments of baitfish are transported great distances from where they were collected, and thus pose a risk of transporting invasive species into new areas. Because baitfish are typically small minnow species (of the family Cyprinidae) and are transported by the thousands, there is a risk for just a few similarly sized invasive fishes to be included, and it is virtually impossible to visually detect and completely remove unwanted species from the hauling tanks. In partnership with private industry, we have developed a loop-mediated isothermal amplification (LAMP) assay that can be used with a portable instrument to detect environmental DNA of bigheaded carps (*Hypophthalmichthys molitrix* and *H. nobilis*) mixed with live bait from a water sample on-site in under one hour. Additionally, the process has been simplified so that individuals without previous experience in genetics or molecular laboratory techniques can perform the test with minimal training and get the same results as an expert user. The use of this technology by law enforcement officers and individuals involved in the bait industry should greatly reduce the risk of invasive species spread by this pathway.

NOTES

How Much Can Environmental DNA (eDNA) Reflect a Local Macroinvertebrate Community in a Freshwater Flowing Habitat?

Rosetta C. Blackman
University of Hull, School of Biological, Biomedical & Environmental Sciences

The use of eDNA as a monitoring tool in closed freshwater systems (ponds, lakes etc) has been well explored. In this project we focus on comparing established macroinvertebrate sampling techniques (kick sampling) with eDNA samples, taken from sediment, water and biofilms at the same sites. Current methods of monitoring macroinvertebrates in freshwater rely heavily on the capture or sighting of the target species, which is not always possible. This is particularly true when referring to invasive alien species (IAS) which can be cryptic, in low density or in juvenile stages. This makes eDNA a particularly interesting complimentary tool when assessing macroinvertebrate communities and as an early warning system for new IAS. Here we demonstrate the findings of a series of catchment surveys carried out in line with the UK Environment Agency monitoring to evaluate the effectiveness of this new tool for detecting new and emerging IAS.

NOTES

Environmental DNA (eDNA) as a Monitoring Tool for Zebra Mussels in Lake Winnipeg

Timothy Gingera[1], *Robert Bajno*[2], *Margaret Docker*[1], *Jim Reist*[2]
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[2] *Fisheries and Oceans Canada*

Zebra mussels (*Dreissena polymorpha*) were first discovered in Lake Winnipeg in the fall of 2013 and their presence has since been confirmed in four harbours within the southern basin as well as on numerous floating objects outside of the four invaded harbours. While potash treatment was successful in temporarily eliminating zebra mussels from the harbours in the summer of 2014, individuals were able to re-establish themselves within the harbours post-treatment. Focus has now shifted from eradication to containment of spread into adjacent waterbodies as well as further west into Saskatchewan and Alberta. Now more than ever there is a need for early detection of these invaders in order to protect our native habitats and economic interests. Environmental DNA (eDNA) is useful as a detection tool to infer the presence of targeted organisms in a water body through collection and identification of species-specific DNA. Given its sensitivity, eDNA is often effective at detecting organisms before they are detectable by traditional sampling. This tool has already been deployed by resource agencies for detecting and monitoring other invasive species such as Asian carps; with appropriate development and testing, eDNA can likewise be used for detecting zebra mussels in Manitoba and other provinces. The research presented here will discuss the use of eDNA techniques for detecting zebra mussels, as well as the development of a set of novel genetic markers that together will detect both zebra mussel and another potential invader in Manitoba, the quagga mussel (*D. bugensis*). Using water samples taken from the southern basin of Lake Winnipeg during the summers of 2014 and 2015, we evaluate the feasibility of using eDNA to infer the spread of zebra mussels at the beginning of the invasion. This work has direct implications to the development of zebra mussel monitoring in western Canada.

NOTES

Development and Testing of High Throughput Sequencing Assays to Detect Aquatic Invasive Species from Environmental Samples

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Environmental DNA (eDNA) surveys are being integrated into management plans for the early detection of aquatic invasive species. The technique involves the amplification of DNA from shed epithelial cells, or in the case of microscopic organisms, the entirety of the organism, found in water samples, allowing for the identification of species based on DNA sequence. Advances in DNA sequencing technology now allow for the high throughput analysis of samples as well as the ability to identify multiple species from a single sample. This metagenetic approach increases the applicability and feasibility of eDNA tools for wildlife managers concerned with early detection of invasive species. We present data on our current high throughput genetic assays designed to detect invasive, or potentially invasive, fish, bivalve and gastropod species in the Laurentian Great Lakes. We place emphasis on primer design and testing in order to avoid non-target species amplification and amplification bias, a problem that plagues many current applications of metagenetic methods to eDNA samples. Using simulated DNA communities, we test the ability of our assays to measure relative abundance of DNA and potentially relative abundance of species. We also employ internal standards to estimate the assays' limits of detection.

NOTES

Varying Levels of Different Environment Factors Influence the Decay of Aquatic eDNA

Richard F. Lance[1], *Xin Guan*[3], *Heather L. Farrington*[1], *Matthew R. Carr*[3], *Michael G. Jung*[3], *Karen C. Bascom*[3], *Katy E. Klymus*[2], *Kelly L. Baerwaldt*[4]

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[3]*Badger Technical Services*

[4]*U.S. Army Corps of Engineers, St. Paul District*

Surveying for aquatic organisms through the detection of environmental DNA (or eDNA) in water samples is an area of growing interest and expanding application. However, the nature of aquatic eDNA is poorly understood, which limits the power of eDNA surveys to influence management decisions. In our study we performed a series of experiments to better understand how varying levels of different abiotic and biotic factors influence the decay of eDNA originating from waste materials produced by captive bighead carp (*Hypophthalmichthys nobilis*). Trials focused on water turbulence, pH, temperature, and microbial load. We also compared the relative rates of eDNA decay under conditions where the previously tested factors were combined to minimize and maximize degradation. We found no effect of water turbulence on decay. Temperature, however, had a clear impact, with eDNA at warmer temperatures (30° C) decaying with a half-life 5.5X shorter than at colder temperatures (4° C), and intermediate temperatures exhibiting intermediate half-lives (r = -0.966). Different pH levels also appeared to influence decay, with eDNA at pH 8.0 exhibiting a half-life 1.3X shorter than at pHs closer to neutral, and 1.5X shorter than at pH 6.5. Under relatively high levels of microbial loads, eDNA half-life was 300X shorter than when microbial loads were suppressed. Under a treatment with the combined factors at levels favoring rapid degradation, eDNA decayed with a half-life nearly 200X shorter than for untreated eDNA and nearly 400X shorter than eDNA under conditions favoring slow degradation. The data provided in this study demonstrate the significant influences of environmental factors on eDNA decay and, ultimately, on our ability to detect eDNA. An increased capability for taking environmental conditions into account will lead to increasingly powerful, efficient, and actionable eDNA monitoring programs.

NOTES

Improvement of Methods for Detection of Dreissenid Mussels by Microscopy and Polymerase Chain Reaction

Jacque Keele[1], *Jamie Carmon*[2], *Denise Hosler*[1,2]
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[2]*GEI Consultants Inc.*

Reclamation Detection Laboratory for Exotic Species (RDLES) has been doing research to understand the factors that affect the analysis of environmental samples for the detection of *Dreissena polymorphya* (zebra mussel) and *Dreissena rostriformis* (quagga mussel). RDLES uses both cross polarized light microscopy and DNA analysis to assess water samples from across the Western United States for the presence of these invasive mussels. This data are used to track the spread and distribution of the mussels in the West. Research at RDLES has focused on the best methods for preserving and processing the water samples so that if there are Dreissenid veligers present it is possible to detect these organisms. The use of polymerase chain reaction (PCR) to detect the mussel DNA has been technically more difficult than the microscopy testing because of the many different factors that can affect the PCR testing. To understand these factors, a series of experiments were performed to gain a better understanding of why the PCR testing is not always consistent. These studies looked at preservation methods (buffer and alcohol concentrations), the DNA extraction kits, and presence of inhibitors in the water sample. One major finding was that without proper buffering the Maltese cross that is diagnostic for veligers under cross polarized light microscopy disappears, but the DNA is still present and can be detected. This is a major issue because to meet state regulations that consider a water body positive for these invasive mussels it is necessary to have both the body and DNA. By performing experiments to understand the behavior of Dreissenid DNA in environmental samples, RLDES has been able to improve its detection methods and sensitivity. The lessons learned from the analysis of raw water samples for the detection of Dreissenid environmental DNA can be extended to other invasive and endangered organisms.

NOTES

Where is the Body? Dreissenid Mussels, Raw Water Testing, and the Real Value of E-DNA

Denise M. Hosler *and Jacque Keele*
Bureau of Reclamation

The Bureau of Reclamation has been monitoring the waters in the western U.S. since 2006 for the presence of dreissenid mussels. Currently, Reclamation has evaluated over 15,000 raw water samples representing over 400 western water bodies. This body of data includes water bodies where mussels had invaded and control methods were being tested. Primarily however, the program tested western waters for the purposes of tracking the dreissenid mussel invasion. Utilizing the USACE program for zebra mussel detection, Reclamation developed a protocol for raw water testing for determination of dreissenid mussel presence in western waters that included microscopy and DNA testing. The results of testing clashed with definitions, and triggered concerns for costly false positives that round robin testing did not substantiate. During that time, a clear understanding of the conflicting test results was not available for the stakeholders and partners participating in the mussel detection program. The large body of data revealed some unique information on the invasion of mussels in the western U.S.; from the way samples were collected and preserved, to the slower than anticipated spread. The Reclamation Detection Laboratory for Exotic Species (RDLES) conducted research looking more closely at the science involved in the detection of invasive mussels in raw water plankton tow net samples. As research revealed information about the lack of microscopic findings, the value of E-DNA findings for invasive species and mission essential projects became apparent. This presentation will present an overview of the Reclamation invasive mussel program detection, monitoring, and briefing on some control research activities. Some of the RDLES research developments that have far-reaching applications for future management activities and decisions will be presented. Emphasizing many of the lessons learned from this large body of data and the related discovery of benefits of E-DNA testing for numerous species of concern.

NOTES

Canada's Aquatic Invasive Species Regulations

Tracy Kerluke *and Rachelle Duval*
Fisheries and Oceans Canada

Fisheries and Oceans Canada's new *Aquatic Invasive Species Regulations* came into force in May 2015. This presentation will provide an overview of the Regulations which provide a national regulatory framework to help prevent intentional and unintentional introductions of aquatic invasive species in Canada from other countries, across provincial and territorial borders and between ecosystems within a region. It also provides a full suite of regulatory tools under the federal *Fisheries Act* to prevent the introduction of aquatic invasive species into Canadian waters and to control and manage their establishment and spread, once introduced.

The Regulations complement existing federal and provincial authorities and bridge gaps within these frameworks to enable a broad range of AIS management activities, such as the possibility to issue directions to prevent imminent introduction.

NOTES

The Roles and Responsibilities of Health Canada's Pest Management Regulatory Agency

Scott Couture
Health Canada, Pest Management Regulatory Agency

The presentation will outline the roles and responsibilities of Health Canada's Pest Management Regulatory Agency. The regulatory process for pest control products in Canada with special regard to emergency registrations and invasive alien species will be discussed.

NOTES

BC Invasive Mussel Prevention Program

Martina Beck *and Leif-Matthias Herborg*
BC Ministry of Environment

The province of BC is involved in cross-jurisdictional collaboration and partnerships with all levels of government, academia and non-governmental organisations addressing invasive species. In 2009, B.C. signed on as a partner in the Columbia Basin Rapid Response Plan, along with U.S. federal, Tribal and state agencies from Washington, Oregon, Idaho and Montana. The Province continues to develop and implement a perimeter defence plan for zebra and quagga mussels with neighbouring jurisdictions including Washington, Oregon, Idaho, Montana, British Columba, Alberta and Saskatchewan. British Columbia's enhanced invasive mussel defence program, includes six mobile decontamination units, 12 trained auxiliary conservation officers who perform roadside watercraft inspections and decontaminations, as well as expanded monitoring for zebra and quagga mussels and increasing "Clean, Drain, Dry" education and outreach activities. The program will analyse water samples from sites across BC to monitor for invasive mussels in BC waters. The boater movement data collected as part of the inspection process is forming the basis of a boater movement model for BC, which is being developed by the University of Alberta and will determine the optimum placement of inspection stations in the future.

NOTES

Redefining Norms: Alberta's Approach to Aquatic Invasive Species Prevention and Management

Kate Wilson *and Tanya Rushcall*
Alberta Environment & Parks

Alberta's Aquatic Invasive Species Program has advanced from being nonexistent to a comprehensive and multi-faceted provincial program that has achieved broad-based public and stakeholder support in a short amount of time. The foundation of this program is based on incredible agency and stakeholder partnerships, collaborative opportunities, and capitalizing on the experience of others, while making efficient use of available resources.

While there are many aquatic invasive species (AIS) that pose a risk to Alberta waters, quagga and zebra mussels (*Dreissena rostriformis, Dreissena polymorpha*) are a significant concern due to the threats they pose to water conveyance infrastructure and the aquatic environment. Alberta is home to the most irrigation infrastructure in Canada, and this is a very tangible threat. An economic impact assessment conservatively estimates annual costs to Alberta in the event of an invasive mussel infestation to be more than $75 million. While the initial focus of the AIS Program was dreissenid mussels, it has since progressed to become multi-taxa in scope.

The AIS Program includes the following elements: watercraft inspections, monitoring, education & outreach, response, and legislation & policy. Mandatory watercraft inspection stations are conducted throughout the province, focusing on high risk areas (e.g. borders). The *Fisheries (Alberta) Act* was amended in 2015 to allow for a more robust approach to prevention and management – including a prohibited AIS list of 52 aquatic invasive plants, invertebrates and fish. Two educational campaigns focused on behaviour change and social marketing have been launched. Monitoring for invasive mussels has been initiated in over 60 lakes and reservoirs in the province annually. Response plans have been developed for areas of highest concern. Just recently, Alberta was the first province to exercise the authorities provided in the new federal AIS Regulations under the *Fisheries Act* to eradicate an infestation of Black Bullhead (*Ameiurus melas*).

NOTES

Introduction to the New Ontario Invasive Species Act

Ala Boyd
Ontario Ministry of Natural Resources and Forestry

In November 2014 the Ontario Government introduced Bill 37, An Act respecting Invasive Species. Development of the legislation followed the release of the Ontario Invasive Species Strategic Plan in 2012 which highlighted the need for an improved legislative framework to address Invasive Species management in Ontario. The existing patchwork of 20 federal and provincial Acts relied upon in Ontario contained gaps and inconsistencies which have put natural environment and associated socio-economic benefits at risk.

The purpose of the legislation is to:

- Provide a stronger legislative framework to prevent, detect, eradicate and manage invasive species;
- Promote shared accountability for managing invasive species;
- Be a risk-based approach that considers the full range of risks and costs to the environment, society and the economy; and
- Complement the role the federal government has to manage invasive species.

To achieve these objectives the legislation provides a suite of scalable powers to enable management actions ranging from prevention to eradication. The legislation will also allow Ontario to increase collaboration and harmonization with neighboring jurisdictions.

An overview of the legislation and the approach Ontario intends to take with respect to the implementation of the Act will be discussed.

NOTES

Inter-assessor Reliability of Risk Classifications for Invasiveness of Alien Species

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New regulation of the European Union (EU) sets out rules to prevent adverse impact on biodiversity of the introduction and spread of invasive alien species (IAS). Therefore, the European Commission will adopt a list of IAS of Union concern. An IAS can only be included on this list if it is demonstrated through scientific evidence that the species is likely to have a significant adverse impact on biodiversity or related ecosystem services. Moreover, a sound risk assessment should provide guidance on whether concerted action at EU level is required. The risk assessment must be carried out with respect to the current and potential range of IAS in association with a set of assessment criteria. Earlier studies demonstrated that for 72% of the alien species assessed, risk classifications between countries disagreed. Differences between risk classifications occur due to variation in (1) assessment protocols, (2) biogeographical regions, (3) data availability, and (4) inter-assessor reliability. We analysed the risk assessments of multiple experts in order to quantify inter-assessor reliability of risk scores for the invasiveness of twenty alien species (aquatic plants, molluscs and fish). All risk assessors applied the same protocol, biogeographical setting and knowledge document to their risk assessment. Agreement of risk classifications per species varied between 50 and 90 percent. Important sources of inter-assessor variability are subjective judgment of effect criteria, lack of quantitative criteria for 'significant' adverse impact and data deficiencies. The implications of our results for applications of risk assessments within a legal context are discussed. The reliability of risk classifications may be increased by (1) the improvement of assessment criteria for effects on biodiversity and alteration of ecosystem functioning, (2) the use of panels with trained risk assessors, (3) increasing the transparency of uncertainties in risk assessments, and (4) introducing quality assurance procedures such as peer review.

NOTES

Comparing European Risk Assessments for Invasive Freshwater Invertebrates

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During the last decade, separate risk assessments for invasive species have developed in many EU countries in response to targeted biodiversity management strategies. These have been promoted by national agencies and/or by individual scientists. Risk assessments vary in scope; some focus on probability of establishment and/or invasion, while others also account for their potential to cause ecological or economic impacts. Alien Challenge is an EU COST action tasked with enhanced knowledge gathering and sharing through a network of experts, providing support to a European IAS information system to enable effective and informed decision-making in relation to IAS (www.brc.ac.uk/alien-challenge) with one working group comparing multiple impact risk assessment across eight major taxon groups, including freshwater invertebrates, to test for consistency and uncover trends and differences across protocols.

Six invasive freshwater invertebrates were each assessed by at least five scientists using nine different European protocols. The species assessed were the killer shrimp *Dikerogammarus villosus*, zebra mussel *Dreissena polymorpha*, crayfish *Procambarus clarkii*, bloody red shrimp *Hemimysis anomala*, apple snail *Pomacea canaliculata* and jellyfish *Craspedacusta sowerbii*. The results were consistent across protocols and assessors, with *P. clarkii* and *D. polymorpha* consistently identified with highest impact ranking scores and *C. sowerbii* assessed as lowest scoring invader. Assessors were then asked for feedback, via survey monkey, on the clarity, user-friendliness, level of expertise required and on estimation of the expected result.

Although in the long term it is possible that one EU-wide risk assessment may be selected in line with the new EU regulation on invasive species, there is little doubt that individual risk assessments used in this exercise will still be used for regional assessments.

NOTES

Prioritizing Species of Concern Under Projected Climate Changes Using a Temperature Matching Model

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Changing climate conditions are likely to impact the dispersal and establishment of aquatic invasive species. Our goal was to prioritize the species of highest concern for the Great Lakes basin and the province of Ontario, and to understand how this list may change under different climate scenarios. We performed a risk assessment of species of concern by matching species habitat requirements with the Intergovernmental Panel on Climate Change (IPCC)'s Fifth Assessment Report (AR5) climate models over the next century. The suitable temperatures for survival, reproduction and growth of fish were identified and compared to statistically downscaled temperature projections under three representative concentration pathways from the AR5 (2.6, 4.5, and 8.5) and over three time periods (2011-2040, 2041-2070, and 2071-2100). The likelihood of species spread was evaluated for key fish species that are already established in the Great Lakes basin, as well as a list of potential invaders compiled from the literature. This temperature-matching model allowed us to create a list of the most likely invaders in each scenario, and to identify which parts of the Great Lakes basin and the province of Ontario are most at risk of hosting new species. These predicted futures allow adaptive management practices to be developed under multiple possible climate change scenarios.

NOTES

Invasion Risk of AIS Not In the Great Lakes Under Future Climate Scenarios

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The Michigan Department of Natural Resources and Department of Environmental Quality partnered with the University of Wisconsin-Madison on a GLRI funded project to create downscaled climate predictions for the Great Lakes Basin. These predictions are at a fine enough spatial scale to capture differences in climate variables influenced by lake-effect and map predictions of future suitable climate for a suite of invasive species. Our study targeted species that are not currently climate matched in the Great Lakes Basin, but are clearly invasive elsewhere. We then assessed their potential invasion risk under future climate projections using the downscaled climate data. This study was explorative in nature, to investigate whether sufficient data on the selected species native ranges and habitat requirements were available to make strong predictions about the potential suitability of habitat in the Basin under future climate change scenarios. These predictions, along with identification of similar, appropriate habitat in the basin and likely pathways of arrival for the selected species, will allow the Great Lakes States to more effectively target AIS monitoring and Early Detection and Response efforts in the future. Linking the risk of invasion to habitat types and climate scenarios in a spatial context provides a powerful framework for focusing adaptive management work.

NOTES

Conquering the Cold: Climate Suitability Predictions for the Asian Clam in Cold Temperate North America

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The Asian clam (*Corbicula fluminea*) is a highly invasive freshwater bivalve that can exert strong ecological and economic impacts and is now established on every continent except Antarctica. New research suggests that the species is tolerant of cold temperate climates and that it is expanding into natural water bodies in cold temperate regions previously thought to be invulnerable to invasion. New populations have been detected in British Columbia's Lower Mainland region, on Vancouver Island and in southwestern Ontario. Climate suitability modeling techniques can be used to identify regions at risk of being invaded and prioritize them in monitoring programs. We present a MaxEnt model that predicts the climatic suitability of North America for the Asian clam under current and future climate regimes. The results indicate that the Asian clam poses a significant invasion risk to waterways in cold temperate regions; in particular, some southern regions of Canada are at risk of an Asian clam invasion. Efficient monitoring, control and awareness programs are required to prevent the continued spread of this invader in North America.

NOTES

Invasion history of *Dreissena polymorpha*, the Zebra Mussel in Lough Key, an Irish Lake

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The zebra mussel (*Dreissena polymorpha*) arrived in Ireland circa 1993 and spread to Lough Key, Co. Roscommon, from the interconnected River Shannon in the late 1990s. The mussels were monitored annually in this 9km^2 lake between 1998 and 2003. The zebra mussel population (density and biomass) in Lough Key was assessed using a combination of snorkel and dive techniques along lake transects. In 2003, the population estimate was six billion (6x10^9) with high cover of zebra mussels on stones in near-shore areas of the lake. This invasion resulted in the extirpation of the only native unionid present (*Anodonta*), with no live specimens recorded in this study after 2000.

In summer 2015, the transect survey was repeated to assess changes in the zebra mussel population after a twelve year gap in monitoring. The survey also assessed whether *Anodonta* had managed to recolonize the lake. This presentation on the invasion history of the zebra mussel in an Irish lake will indicate whether this invader has exhibited a boom-bust cycle or is undergoing annual oscillations in population dynamics. Trends in water quality and an assessment of changes in the trophic status of Lough Key will also be presented.

NOTES

Zebra Mussel Habitat Selection, Growth and Mortality in Lakes of Northeastern Wisconsin and the Upper Michigan

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Zebra mussels (*Dreissena polymorpha*) are being transported by anthropogenic mechanisms and through natural corridors from the Great Lakes to inland lakes in northern Wisconsin and Upper Michigan. With limited zebra mussel management options, there is a need to contain the spread through early detection monitoring. Suitability models based on water calcium concentrations currently assist managers by identifying which lakes to focus pre-invasion monitoring efforts. Knowledge of lake-specific habitat limitations will help refine monitoring efforts by identifying locations within lakes that have high invasion potential. Additionally, quantitative comparisons of population dynamics among lakes across a range of colonization periods will provide information to managers and landowners on anticipated population trajectories following establishment. The objective of this study was to determine zebra mussel habitat preferences and population dynamics within and among lakes in northern Wisconsin and upper Michigan. SCUBA diving was used to sample quadrats at regular intervals along transects representing a variety of substrate types and water depths. Within quadrats, water depth and substrates were recorded to quantify habitat availability. Presence and density of zebra mussels, substrates zebra mussels were attached to, as well as zebra mussel age and length were examined to assess zebra mussel habitat preference, growth, and mortality. Results indicate that substrate selection is occurring within lakes, and among lakes there is a difference in zebra mussel growth, but no difference in mortality. These results will improve early detection monitoring and provide baseline understanding of anticipated zebra mussel growth and mortality following establishment.

NOTES

The Status of Quagga Mussel Populations in Lake Michigan and Complementary Growth Experiments

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The introduction of invasive zebra and quagga mussels (*Dreissena polymorpha* and *D. rostriformis bugensis*, respectively) has profoundly impacted the Great Lakes basin and other areas across North America. The NOAA Great Lakes Environmental Research Laboratory has been conducting surveys of the benthic community in southern Lake Michigan since before dreissenid mussels were introduced. As a result, we have annual data that details the population dynamics of both species from the very beginning of their initial, rapid expansions. We will present updated survey data, which reveals depth-specific population trajectories, including declines in biomass at 30-50m and 50-90m and increases at depths >90m. Further, length-weight relationships show that mussels in the 30-50m depth zone have the lowest biomass for a given shell length. To explore what is influencing these observed changes in quagga biomass, we are conducting complementary field and lab growth experiments. The goals of the field experiment are to measure quagga mussel growth year-round and also test the efficacy of using Calcein, a fluorescent marker, to track growth of individuals. The mussels are contained in cages at a depth of 45m in Lake Michigan near the coast of Muskegon, Michigan, USA. To check for cage effects, we will compare condition of the caged mussels to uncaged background mussels. Initial field trials are in progress and we will present findings from the first stage of this project. We are also conducting a lab experiment to compare quagga growth in response to food levels that represent conditions in Lake Michigan at the beginning of the quagga mussel invasion (high) and present day (low). The results from these studies will help to elucidate the population trajectories of quagga mussels in Lake Michigan. These findings are also informative for the current expansion of dreissenid mussels in the West.

NOTES

Regional Collaboration to Protect the Great Lakes and St. Lawrence River

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The Great Lakes and St. Lawrence River system is shared by eight U.S. states and two Canadian provinces, contains about 20 percent of the world's surface fresh water, and supports a $7 billion fishery. Collaboration among the states and provinces is necessary to act on serious threats from aquatic invasive species (AIS) that can spread throughout the system's connected lakes and rivers, thereby affecting the region's environmental and economic health. Through the Conference of Great Lakes and St. Lawrence Governors and Premiers (Conference), the region's chief executives work together to protect the system from AIS. The Conference's AIS Task Force coordinates state and provincial efforts and spearheads joint regional action.

In 2015, the Governors and Premiers completed an innovative Mutual Aid Agreement to facilitate cooperative response actions and the sharing of staff, expertise and resources if a new regional AIS threat is detected. The Conference supported the Task Force in developing this agreement in partnership with Great Lakes Fishery Commission experts. The agreement is broadly designed to:

- Help prevent the introduction and spread of AIS.
- Foster mutual aid among the States and Provinces to respond to serious threats from AIS.
- Encourage further cooperative actions by the States and Provinces to combat AIS.

All ten jurisdictions are party to this agreement, and implementation has commenced. Building on this success and subsequent analysis by the Province of Ontario and the Great Lakes Fishery Commission, Michigan, Ohio and Ontario are developing an innovative pilot project to harmonize AIS regulations and increase cooperation among the three jurisdictions. The AIS Task Force will help facilitate this process, and work to develop a model that can include other states and provinces in the future. This presentation will focus on the process to develop the Mutual Aid Agreement, and ongoing regional actions.

NOTES

Considerations in Governance of Aquatic Invasive Species Management – Experience on the International Great Lakes

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Management of aquatic invasive species represents significant challenges because efforts boundaries within natural resource and environmental agencies, among agencies, among States and Provinces, and across borders between countries. The experience dealing with aquatic invasive species in the Laurentian Great Lakes includes all of these challenges and we use this experience as the basis for exploring key principles for successful governance. We describe the significant and continuing successes have been found in the delivery of the international program to control Sea Lampreys (*Petromyzon marinus*) by the Great Lakes Fishery Commission formed under Convention between the Canada and the United States. We describe the successes in the history of the Aquatic Nuisance Species Panel and the Great Lakes Commission's efforts to affect coordination of this United States legislative program. We speak to the roles and responsibilities of the issue-based Asian Carp Regional Coordinating Committee. We present the new framework for aquatic invasive species management presented in the Great Lakes Water Quality Agreement between Canada and the United States and efforts to coordinate the delivery of that framework within existing institutions including those established under the Strategic Plan for Management of Great Lakes Fisheries. We describe the successful establishment of the Council of Great Lakes Governors and Premiers Mutual Aid Agreement and envisioned next steps. We discuss successful planning and coordination of responses and the application of modern emergency planning including the Incident Command System. The Great Lakes have benefited from a history of effective collaboration to tackle fisheries and environmental issues. The principles underlying those collaborations include: clear definition of issues of common concern; clear terms for reaching consensus; clear roles and responsibilities; and recognition of individual jurisdiction legal, regulatory, and policy integrity. These principles are critical to effective governance of the management and prevention of aquatic invasive species.

NOTES

A Risk Assessment of Golden Mussel (*Limnoperna fortunei*) for Ontario

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The Golden Mussel, *Limnoperna fortunei*, is native to freshwaters of China and south-eastern Asia. It became established in Hong Kong in 1965 and in Japan and Taiwan in 1990s. The Golden Mussel was introduced to South America in 1991 through ballast water discharge. It has since expanded to four other countries in South America. The Golden Mussel is not yet present in North America.

A Risk Assessment of Golden Mussel for Ontario was performed by: (i) Assessing probability of invasion by estimating the probability of arrival, survival, establishment, and spread. (ii) Estimating impacts of invasion. (iii) Assessing potential risk from the above two steps.

Ballast water exchange of Atlantic transoceanic vessels from South America was ranked the primary potential pathway for introduction of Golden Mussel directly into the Great Lakes. A "back door" entry into the Great Lakes was also considered via overland dispersal (e.g. trailered boats) from ballast water exchange of transoceanic vessels from Asia to the Pacific coast of North America. However, the overall probability of arrival through these two pathways was ranked low.

The probability of survival, establishment, and spread of golden mussel in Ontario was deemed to be low, primarily because of its physiological intolerance of cold, winter waters that will likely kill any mussels that may survive summer water temperatures. The level of certainty was considered moderate as there has been no Golden Mussel reported from lakes that freeze over in Asia or South America. However, the lower thermal threshold for Golden Mussel needs to be empirically examined. The consequence of establishment was predicted to be of high negative ecological and economic impacts. A climatch analysis using Japan and South America as source regions and Ontario as the target region resulted in very different climates between both sources and Ontario, further suggesting that *L. fortunei* will not likely establish in Ontario.

NOTES

Canadian Columbia Basin: A Collaborative Approach to Aquatic Invasive Species Management

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Central Kootenay Invasive Species Society

In May of 2015, a *Canadian Columbia Basin Aquatic Invasive Species Program Framework* was developed. This Framework was written by Juliet Craig of Silverwing Ecological Consulting on behalf of regional invasive species societies (Central Invasive Species Society (CKISS), Columbia Shuswap Invasive Species Society (CSISS), East Kootenay Invasive Plant Council (EKIPC) and Northwest Invasive Plant Council (NWIPC) and their partners within the Basin.

Regional invasive species organizations in British Columbia are non-profit societies that have no legal land or water management jurisdiction. The organizations conduct outreach and awareness campaigns, in addition to monitoring, treatments and research activities by working in partnership with other organizations. Due to the expansion of the regional organizations aquatic invasive species (AIS) programs, the Framework was developed to promote a proactive, strategic, collaborative and coordinated approach to AIS prevention and management in the region. The development of the Framework has allowed for a more coordinated and collaborative approach to AIS management and prevention within the Canadian Columbia Basin.

In 2015, the regional organizations have worked closely with the Province of BC by conducting sampling for zebra and quagga mussel in accordance with Provincial sampling protocols. In addition, the CKISS and EKIPC have provided the Province with two additional decontamination units to assist in expanding the scope of the Provincial Mussel Defense program within the Canadian Columbia Basin.

The CKISS has been working diligently on creating an American Bullfrog Surveillance strategy, which includes the deployment of acoustic monitoring devices at high priority sites along the US border, visual surveys, eDNA and evaluation of existing eradication strategies. This program is a collaborative effort by the CKISS, industry, the Province and representatives from Washington and Idaho.

This coordinated and collaborative approach to AIS management has allowed the regional organizations to work more effectively and efficiently with its provincial and international partners.

NOTES

Spatial Resolution Effects on Predicting the Distribution of Aquatic Invasive Species in Nearshore Marine Environments

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The most appropriate range of spatial resolutions of environmental data to accurately delimit potential habitat of nearshore aquatic invasive species (AIS) using species distribution models (SDM) is unknown. This study informs the development of risk assessments for nearshore AIS, by determining the optimal range of spatial resolutions of environmental data to predict potential habitat using SDM. We consider two nearshore marine AIS that have spread rapidly around the world's temperate oceans: the vase tunicate (*Ciona intestinalis*) on the East Canadian coast and European green crab (*Carcinus maenas*) on the West Canadian coast. As these species' invasion success in temperate seasonal environments is constrained by temperature and salinity, we correlated these environmental variables at a range of spatial resolutions (100 km-100s m) with both species' occurrence using SDM, specifically Maxent. Increasing spatial resolution of these environmental predictors resulted in more accurate estimates of suitable habitat for West coast *C. maenas* and East coast *C. intestinalis* populations; including a more realistic depiction of their actual ecological niche. The probability of accurately delimiting suitable habitat, and resolving fine resolution patchiness in these species' distributions, was improved considerably at or below spatial resolutions of 8 km for East coast *C. intestinalis* or 4 km for West coast *C. maenas*. Our findings provide new insights as to choice of environmental resolution to optimize prediction of AIS distributions in nearshore marine environments.

NOTES

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Alberta Environment and Parks is charged with promoting healthy, sustainable ecosystems and conserving biodiversity. The Ministry is the proud steward of air, land, water and biodiversity, whose vision is to lead the achievement of desired environmental outcomes and sustainable development of natural resources for Albertans.

Along with fish and wildlife management and, the Fish and Wildlife Policy Branch leads the province-wide Alberta Aquatic Invasive Species Program, a relatively recent development. The Alberta Aquatic Invasive Species Program is a Cross-Ministry partnership comprised of five program elements:

- Policy and Legislation;
- Education and Outreach;
- Watercraft Inspections;
- Monitoring; and
- Response.

Aquatic invasive species are one of the greatest threats facing Alberta's freshwater resources, including aquatic habitat and fisheries, but also the economy and the industries that fuel it, such as the irrigation industry. Alberta is home to the largest irrigation infrastructure in Canada and as such, has much to lose in the event of an infestation of aquatic invasive species. The Alberta Aquatic Invasive Species Program has benefited from excellent stakeholder support and prevention of aquatic invasive species has become a priority in recent years for the province.

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The introduction of the zebra mussel, and later the quagga mussel, to North America has had major impacts on water users throughout the continent. These tiny molluscs can deeply impact the integrity of water supply systems forcing each individual user to seek out methods of remediation.

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We are a full-service engineering and technology based company with a focus on all aspects of underwater infrastructure inspections, maintenance, and repair; as well as the design, build and operation of water and wastewater treatment facilities.

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Atlantium Technologies, Ltd. is a proven control for macro (zebra & quagga mussels) and micro bio fouling. As well as, a proven solution for chemical free dechlorination and disinfection to protect RO membranes.

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Delta Waterfowl is The Duck Hunters Organization™, a leading conservation group with origins dating to 1911. Headquartered in Bismarck, North Dakota, and Winnipeg, Manitoba, Delta Waterfowl has developed several key programs – including Predator Management, Hen Houses and First Hunt – all of which are based on sound science. Delta works to produce ducks, conserve breeding duck habitat, enhance duck hunting opportunities and ensure the continuing tradition of duck hunting in North America.

Delta works hard to be "the voice of the duck hunter". Delta's network of chapters and volunteers serve as the eyes, ears and impactful voices to secure positive outcomes for duck hunters on local issues. It is this network of passionate waterfowlers who care about hunting in their communities, paired with Delta's years of accumulated experience on how to get things done that make a formidable team on behalf of the duck hunter.

Our Mission:
To produce ducks and secure the future of waterfowl hunting.

Our Vision:
Abundant waterfowl and endless opportunities for hunters.

Membership:
Delta members are essential to the success of The Duck Hunters Organization. It is their passion that supports our mission and vision.

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Earth Science Labs treats the water we use, drink and play in. ESL is an Arkansas based company that manufactures Earthtec® algaecide and water treatment products including Earthtec QZ and the PristineBlue® line of pool and spa chemicals.

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QZ is NSF-certified to ANSI Standard 60 for drinking water, making it an excellent choice for controlling the spread and infestation of this devastating species. EarthTec QZ can be applied in lakes and reservoirs or in pipelines leading to water treatment plants. It is a rapidly dispersing product and is completely bioavailable. Zebra mussels do not detect it as a threat and readily ingest the QZ. Studies confirm 100% mortality within 4-6 days. It is effective at concentrations that are non-toxic for most non-target organisms.

Advantages of EarthTec QZ:

- Liquid formulation and rapidly dispersing, thus greatly reducing time and labor for application.
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- The copper is formulated in the biologically-active form (as cupric ion, Cu++), and stays in solution until it encounters a cell wall to bind to and penetrate, so virtually all of the copper applied is effective, with no copper or other waste precipitating into bottom sediments.
- History of effective use with no negative impacts on fish and other non-targets.

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The Great Lakes Fishery Commission is an international organization established by the United States and Canada through the 1954 Convention on Great Lakes Fisheries. The commission was established partially as a response to one of the most noxious invaders to enter the Great Lakes system: the sea lamprey. Sea lampreys, primitive fish parasites native to the Atlantic Ocean, invaded the Great Lakes through shipping canals in the early 1900s. Lacking predators, sea lamprey were able to wreak catastrophic damage on the ecosystem and cause significant economic harm to the fishers of the region. The commission's control program has been successful, reducing sea lamprey populations by 90% in most areas of the Great Lakes.

The convention also directs the commission to formulate a coordinated bi-national research program. The program goals are to identify ways to nurture the maximum sustained productivity of Great Lakes fish stocks and, based on that research, to recommend specific management initiatives to the governments. The commission's research program is based upon two broad priorities: research in support of healthy Great Lakes ecosystems and research in support of sea lamprey control. Additionally, the commission directs and supports projects designed to transfer science to managers.

Finally, the commission is charged with facilitating the implementation of A Joint Strategic Plan for Management of Great Lakes Fisheries, a provincial, state, and tribal fisheries management agreement. While there exists no binding, centralized authority to compel cooperative fishery management on the Great Lakes, the jurisdictions realize that the Great Lakes fishery is interconnected and the actions of one jurisdiction affect the others. To manage the resource in this unique setting, the sub-national governments developed and adhere to The Joint Strategic Plan, an agreement that calls for cooperation among the jurisdictions, development of shared fish community objectives, data sharing, and adherence to ecosystem management.

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www.ijc.org

The International Joint Commission prevents and resolves disputes between the United States of America and Canada under the 1909 Boundary Waters Treaty and pursues the common good of both countries as an independent and objective advisor to the two governments.

In particular, the Commission rules upon applications for approval of projects affecting boundary or transboundary waters and may regulate the operation of these projects; it assists the two countries in the protection of the transboundary environment, including evaluating the governments progress toward restoring and maintaining the chemical, physical and biological integrity of the waters under the Great Lakes Water Quality Agreement and the improvement of transboundary air quality; and it alerts the governments to emerging issues along the boundary that may give rise to bilateral disputes.

In 1988, both the International Joint Commission (IJC) and the Great Lakes Fishery Commission (GLFC) alerted the governments of the United States and Canada that aquatic alien invasive species (AIS) in ballast water posed a significant threat to the Great Lakes. The two commissions urged the nations' Coast Guards to take immediate steps to end the ongoing introduction of exotic organisms via ballast water discharge, and having been reporting on AIS issues since.

Invasive Species Centre

Catalyst for research and response

Invasive Species Centre

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The Invasive Species Centre is a non-profit organization that was established in 2011 to connect stakeholders, knowledge and technology to prevent and reduce the spread of invasive species that harm Canada's environment, economy, and society. By working with a broad range of stakeholders, the Invasive Species Centre identifies and fills gaps in knowledge, tools and resources for invasive species management.

Since its inception in 2011, the Invasive Species Centre has led, funded and supported over 185 projects that contribute to invasive species knowledge and management. The projects supported by the organization relate to invasive species prevention, early detection, rapid response, and/or management. While the immediate focus is Ontario and the Great Lakes, the Invasive Species Centre has cultivated partnerships that support invasive species management in the provinces, the U.S. Great Lakes states, and internationally.

The Invasive Species Centre is currently supporting projects related to aquatic invasive species including, but not limited to, detection, monitoring and response to water soldier, European water chestnut, Phragmites, Common Yabby, Hydrilla and Stone Moroko. The organization partnered with Fisheries and Oceans Canada to establish the Asian Carp Canada program which increases Canada's ability to prevent, detect and rapidly respond to Asian carps. Asian Carp Canada provides Canadians with information about the most recent prevention technologies, early warning measures, response efforts, and the overall threat of Asian carps to the Great Lakes and beyond.

For more information, visit www.invasivespeciescentre.ca.

MEIA
Manitoba Environmental Industries Association

Manitoba Environmental Industries Association

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The Manitoba Environmental Industries Association (MEIA) is a non-profit organization that is committed to connecting business, government and interested stakeholders with environmental issues and opportunities. The environment sector represents a sizable industry in Manitoba. A commitment to the environment and positive legislative and policy frameworks have created a context for the growth of the environmental industry in both the domestic and export markets. The goal of the MEIA is to advance business development through networking, advocacy, sharing resources and information, promotion, access to funding, training, collaborations and more.

Manitoba Hydro

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www.hydro.mb.ca

Manitoba Hydro is a Crown Corporation and the province's major energy utility. We generate nearly all our electricity from self-renewing water power using 15 hydroelectric generating stations, primarily on the Winnipeg, Saskatchewan, and Nelson Rivers.

Our position as a leader in renewable energy development has been strengthened with the incorporation of power purchase agreements with two independent wind farms in Manitoba. The addition of wind power to the Manitoba Hydro portfolio complements existing hydroelectric generation, geothermal activities and aggressive energy-conservation programming.

Electricity exported by Manitoba Hydro displaces energy generated outside of Manitoba that would otherwise be produced by fossil-fuelled electric generating stations. In 2014, electricity exports from Manitoba reduced net global greenhouse gas emissions by an estimated 6,600 kilotonnes of carbon dioxide equivalent (CO_2e). This is equivalent to removing nearly **1.4 million vehicles** from the road.

Manitoba Hydro has integrated environmentally responsible practices into all aspects of our operations. We have developed our own principles of sustainable development and have an Environmental Management System that helps us to better manage our environmental risk.

Manitoba Hydro supports many initiatives involving scientific research, environmental monitoring and development of best management practices, and education to foster an understanding of the health of lakes and waterways in Manitoba. This includes our Coordinated Aquatic Monitoring Program, which is the largest holistic, ecosystem-based aquatic monitoring program in Manitoba. Through this program, we assist the province in monitoring lakes and waterways for early detection of zebra mussels. These efforts help gain an understanding of how to protect these bodies of water from the harmful effects of zebra mussels.

Environmental responsibility is an important mandate and one Manitoba Hydro is proud to fulfill. We are committed to reducing our environmental impact and working toward a sustainable tomorrow.

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Marrone Bio Innovations, Inc. (MBI) is a leading provider of biopesticides for use in water and agricultural applications to control pests, weeds, and plant diseases. MBI developed ZEQUANOX® to address the increasing economical and ecological impact of invasive aquatic mussels. The company is also developing solutions for the control of algae and aquatic weeds.

Recognized as a ground-breaking innovation in water technology, Zequanox is the industry's only EPA approved biological molluscicide for controlling zebra and quagga mussels (Dreissena species). Composed of killed cells from a ubiquitous soil microbe (Pseudomonas fluorescens), Zequanox is highly selective; and while lethal to zebra and quagga mussels, it poses no risk to humans, infrastructure, or the environment. Zequanox is nonpersistent and toxicology studies demonstrate that at concentration levels that produce mussel mortality of 76–100%, no product-induced mortality occurs in non-targets, including algae, fish, mollusks, or crustaceans. Zequanox can be used in a broad range of water conditions and temperatures, and has been proven effective for controlling adult mussels as well as reducing settlement. Trials are also underway to validate its effectiveness in controlling veligers (the planktonic life stage of mussels).

Zequanox is registered by the U.S. EPA for use in closed or semi-closed systems, such as service water and irrigation systems, and in open water settings like lakes and streams. No special precautions are required for employees working near Zequanox treatment areas. Zequanox is non-corrosive, and causes no accelerated deterioration of pipes, valves, and other infrastructure as can happen with other chemicals. There are minimal regulatory restrictions on the use of Zequanox, and MBI staff is comfortable and experienced working with regulatory authorities to support obtaining any necessary permits for those wishing to use Zequanox.

Ontario Ministry of Natural Resources and Forestry

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The Ontario Ministry of Natural Resources and Forestry (MNRF) works to promote healthy, sustainable ecosystems and conserve biodiversity. MNRF conducts scientific research and applies the findings to develop effective resource management policies. The MNRF is responsible for managing the fisheries of Ontario and works with partners and agencies to protect, restore and sustain Great Lakes and inland fish species and populations through planning, regulation, scientific study, stocking, and stewardship.

MNRF has the lead provincial role to prevent the introduction, establishment and spread of aquatic invasive species and the negative effects they have on Ontario's environment, economy and society.

MNRF's responsibilities include:

· leadership and coordination of inter-agency activities to prevent, detect, respond and manage

- the threat of aquatic invasive species,

- development and enforcement of legislation and policy,

- risk analysis,

- response planning,

- monitoring and science,

- development of management measures, and

- communications and outreach to the public.

Ontario Federation of Anglers and Hunters

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The Ontario Federation of Anglers and Hunters was founded in 1928 due to concern over the future of Ontario's natural resources. It is Ontario's largest, non-profit, conservation-based organization, representing 100,000 members, subscribers and supporters, and 725 member clubs. OFAH members enjoy various outdoor pursuits, but share a common interest in sustaining our natural resources and the quality of life that healthy resources make possible. As a result, for 88 years, the OFAH has supported programs to conserve and restore fish and wildlife habitat, as well as to help protect our fishing and hunting heritage.

Recognizing the impacts of invasive species and the role of outdoor enthusiasts in their introduction and spread, in 1992 the OFAH initiated the Invading Species Awareness Program in partnership with the Ministry of Natural Resources and Forestry, with the objective to raise public awareness of invasive species and to engage support and participation in prevention, monitoring and control measures. The program is focused on the primary pathways of invasion and encourages citizen reporting of invasive species via the toll-free Invading Species Hotline and online reporting system (www.eddmaps.org/ontario). Through our partnership with the Government of Ontario to deliver this province-wide program, the ISAP has become a leader in invasive species education and awareness in Ontario, and has achieved enormous success in raising the profile of invasive species by working with industry leaders, government agencies, other ENGOs, universities, and a variety of community groups to reach our target audiences.

For more information on the Invading Species Awareness Program, please visit www.invadingspecies.com or call the Invading Species Hotline at 1-800-563-7711.

ONTARIO POWER GENERATION

Ontario Power Generation

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Ontario Power Generation (OPG) is Ontario's largest clean electricity generator. In 2014, OPG stopped using coal to make electricity. It was North America's largest single action to combat climate change. Today, the company's diversified generating portfolio, which is 99.7 per cent free of smog and greenhouse gas emissions, consists of two nuclear, 65 hydroelectric, and three thermal generating stations. We're dedicated to making sure our generating stations continue to provide clean, reliable power at about half the cost of other generators.

Pacific States Marine Fisheries Commission

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Established in 1947 by consent of Congress, the Pacific States Marine Fisheries Commission (PSMFC) is an interstate compact agency that helps resource agencies and the fishing industry sustainably manage our valuable Pacific Ocean resources in a five-state region. Member states include California, Oregon, Washington, Idaho, and Alaska. Each represented by three Commissioners.

RESEARCH INSTITUTE
NATURE AND FOREST

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The Research Institute for Nature and Forest (INBO) is the Flemish research and knowledge centre for nature and its sustainable management and use. INBO conducts research and supplies knowledge to all those who prepare or make the policies or are interested in them.

As a leading scientific institute, INBO works for the Flemish government primarily, but also supplies information for international reporting and deals with questions from local authorities. In addition, INBO supports organisations for nature management, forestry, agriculture, hunting and fisheries. INBO is a member of national and European research networks. It makes its findings available to the general public.

INBO employs some 250 staff, mainly researchers and technicians.

With regard to aquatic invasive species (AIS) INBO plays a lead role in research, monitoring and management of these invasives in the northern part of Belgium. Current AIS research topics include: monitoring of spread and impact of Ponto-Caspian gobies, management of American bullfrog, drafting and reviewing risk assessments for invasive alien species, horizon scanning of new AIS, monitoring and surveillance of AIS, the publication of open data on invasives as well as the development of registries and data warehouses. The institute is a key player in implementing the recently approved European Union Regulation on the prevention and management of invasive alien species list.

INBO scientists liaise with European and other international experts on AIS to tackle the issue on a pan-European or worldwide scale. Results of these collaboration can be found in reports to managers and stakeholders and in numerous peer reviewed papers. The institute was involved in several outreach activities such as the Interreg project Invexo (http://www.invexo.be/), RINSE (http://www.rinse-europe.eu/, Reducing the Impacts of Non-native Species in Europe) and SEFINS (Safeguarding the Environment from Invasive non-native Species) which seek to improve awareness on the invasive species issue, and to develop methods to address them.

Research
Manitoba

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Research Manitoba, established in June 2014, promotes, supports, and coordinates the funding of, research in the health, natural and social sciences, engineering and the humanities in Manitoba. In support of research in the province, Research Manitoba builds and sustains capacity for world class research; encourages and optimizes effective collaboration and connections at every stage of the research continuum; and encourages the dissemination and application of knowledge generated from research to have the greatest possible impact.

For more information, visit: www.researchmanitoba.ca.

Environmental Laboratory
US Army Engineer Research
and Development Center

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The Environmental Laboratory at the U.S. Army Engineer Research and Development Center, Vicksburg, MS, is the problem solver for the U.S. Army Corps of Engineers and the Nation in environmental science and engineering. The laboratory supports the environmental missions of the U.S. Army, the Department of Defense, and the Nation through research, development, special studies, and technology transfer. The Environmental Laboratory conducts multi-disciplinary research in environmental quality and ecosystem restoration. Research activities include: evaluating and projecting the consequences of water resources development, navigation, and dredging on the environment; developing improved tools and metrics for environmental benefits analysis; assessing and restoring wetlands; evaluating and modeling inland and coastal water quality; guiding stewardship of natural resources; developing tools for cleanup of contaminated groundwater and soils; developing techniques to improve stream and riparian restoration; accelerating growth of desirable vegetation/habitat; implementing risk and decision frameworks in planning; forecasting potential impacts from climate change and sea level rise on coastal ecosystem restoration, identifying and applying biological, chemical, and physical control strategies for the management of nuisance and invasive aquatic plants and animals; applying risk-based contaminated sediment and soil toxicological assessment protocols; and performing upland disposal testing and assessment for dredged material.

U.S. Geological Survey

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As part of its mission to provide impartial information on the health of our ecosystems and environment, the natural hazards that threaten us, the natural resources we rely on, the impacts of climate and land-use change, the U.S. Geological Survey conducts science to support sound management and conservation of our Nation's biological resources. It does this through research, technical assistance, and education conducted by Cooperative Research Units and Science Centers located in nearly every State. In the Invasive Species and Wildlife Disease Program, USGS scientists work with Federal, State, local, and other partners to prevent, detect, and identify invasive species and wildlife disease using advanced technologies. USGS biologists also predict potential distribution and impact of invaders, develop and test methods of containing and controlling them, work with partners to determine effective restoration measures after control has been applied, and make data and data visualization tools broadly available. Examples of current USGS aquatic invasive species research include a research program to prevent Asian carp from becoming established in the Great Lakes (http://cida.usgs.gov/glri/#/Home/AsianCarp), co-leadership of a collaborative in the Great Lakes to control Common Reed (Phragmites) (http://greatlakesphragmites.net/); data delivery and visualization of aquatic invasive species occurrences (http://nas.er.usgs.gov); co-leadership of an invasive mussel collaborative (http://glc.org/projects/invasive/mussel/).

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