12th International Conference on Aquatic Invasive Species

Abstracts

June 9 to 12, 2003

The Cleary International Centre
Windsor, Ontario, Canada

Hosted by the Ontario Ministry of Natural Resources

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Monday, June 9

Science, Policy and Politics: An Agenda for Change

Session Chair: Peter Wallace, Assistant Deputy Minister, Natural Resources Management Division, Ontario Ministry of Natural Resources

8:15
Welcome/Introductory Remarks
The Hon. Jerry Ouellette, Minister, Ontario Ministry of Natural Resources (Invited), Canada

8:30
Keynote Presentation
The Rt. Hon. Herb Gray, Chair, Canadian Section, International Joint Commission, Canada

8:45
Keynote Presentation
The Hon. Dennis Schornack, Chair, United States, International Joint Commission, USA

9:00
Invasive Species: A Destructive Force Has Met Limited Resistance – A 2002 Report of the Office of the Auditor General of Canada
Johanne Gélinas, Commissioner for the Environment & Sustainable Development, Office of the Auditor General of Canada, Canada

9:20
The US Federal Government Approach to Managing Invasive Species: Clearer Focus and Greater Commitment Needed to Effectively Manage the Problem
Patricia McClure, US General Accounting Office, USA

9:40
Directions in Policy and Action on Aquatic Invasive Species in the United States
Timothy R. E. Keeney, Deputy Assistant Secretary of Commerce for Oceans and Atmosphere, NOAA, USA

10:10
Break

10:30
Discussion Forum
Moderator: Greg Ferrant, Government Relations and Communications Manager, Ontario Federation of Anglers and Hunters

12:00-1:30
Luncheon

International Perspectives on AIS Management

Session Chair: Edwin A. Theriot, US Army Engineer Research and Development Center

1:30
There's Something Weird in Your Neighbourhood, Who Ya Gonna Call?! Responding to Marine Biosecurity Events in New Zealand
Chris O'Brien, Ministry of Fisheries, New Zealand

2:00
Invasive Alien Species in Africa's Wetlands: Pathways, Impacts, and Solutions
Geoffrey W. Howard, IUCN – The World Conservation Union, Africa

2:30
The US Army Corps of Engineer Aquatic Nuisance Species Research Plan
Alfred F. Cofrancesco, Jr., US Army Engineer Research and Development Center, USA

3:00
Stewarding a North American Approach to Prevent the Introduction and Spread of Aquatic Invasive Species
Hans Herrmann, Biodiversity Conservation Program at the Commission for Environmental Cooperation, Canada

3:30
Break

4:00
Turning the Tide: Is Aquatic Bioinvader Research Heading in the Right Direction?
Geoffrey R.F. Hicks, Department of Conservation, New Zealand

4:30
International Mechanisms for the Responsible Use of Introduced Species in Aquaculture and Fisheries in Inland Waters
Matthias Halwart, Food and Agriculture Organization of the United Nations, Fisheries Department, Italy

5:00
Global Documentation of Fish Introductions – The Growing Crisis and Recommendations for Action
Christine Marie V. Casal, Fish Base Project, World Fish Center, Philippines

6:00
Poster Session

Tuesday, June 10

Concurrent Session A

Control Options for Industry I

Session Chair: Richard F. Green, Constellation Energy

8:30
Introduction to Macrofouling Control for North American Industry Using Surface Freshwater
Renata Claudi, RNT Consulting Inc.

8:50
The European Experience
Hank Jenner, KEMA Power Generation and Sustainables, The Netherlands

9:10
US Navy Approach to Seawater Systems Biofouling Control
Edward J. Lemieux, Center for Corrosion Science & Engineering, Naval Research Laboratory, USA

9:30
Fish Diversion Systems for Invasive Species Applications
Paul Patrick, Kinectrics, Canada

9:50
High-Power Electron Beam Treatment: A Control Technology for Invasive Species
Peter McIntyre, Texas A&M University, USA

10:10
Break

10:40
Effects of a Pulse-Power Electric Field on Settlement Rates of Zebra Mussels on Structures and the Presence of the Asiatic Clam in Sediments
A. Garry Smythe, Stantec Consulting Services Inc., USA

11:00
Application of the Ever Clear™ Filter for Removing Mussels at Industrial Water Intakes
Paul Patrick, Kinectrics, Canada

11:20
State Fish Hatcheries and Invasive Species Don't Mix
Marcus Allhands, Amiad Filtration Systems, USA

11:40
Efficacy of Ozone for Control of Macrofouling in an Industrial Raw Water System
Ron Larocque, Hankin Ozone, Canada

12:00
Luncheon

Concurrent Session B

Ecosystem Interactions and Impacts I

Session Chair: Ron Dermott, Department of Fisheries and Oceans

8:30
Recent Trends of Nonindigenous Aquatic Species in the Temperate Regions of North America
Amy J. Benson, US Geological Survey, USA

8:50
Patterns and Mechanisms of Species Replacement Among Invasive and Native Amphipods
Michelle E. Palmer, Redpath Museum, McGill University, Canada

9:10
Competition Between Exotic and Indigenous Gammarids
Marielle van Riel, University of Nijmegen, The Netherlands

9:30
Do Bio/Ecological Traits Promote the Invasion Success of the Amphipod Dikerogammarus vilosus in Western Europe?
Simon Devin, University of Metz, France

9:50
***Dikerogammarus villosus*, a Ferocious Omnivore**
Dirk Platvoet, University of Amsterdam, The Netherlands

10:10
Break

10:40
Ecological Impacts of Invasive Aquatic Amphipods (Crustacea): Patterns, Mechanisms and the European Lesson for North America
Jamie T.A. Dick, Queen's University Belfast, Northern Ireland

11:00
An Analysis of the Exotic Aquatic Invasions in the Rhine Delta
Gerard van der Velde, University of Nijmegen, The Netherlands

11:20
Dreissenid Mussels in Eastern Lake Ontario and the Upper St. Lawrence River: A 10-Year Follow-up Survey of Navigational Buoys
David Bruce Conn, Berry College,USA

11:40
Ponto-Caspian Crustaceans in the Inland Waters of Lithuania: Introduction, Current Distribution, Factors for Survival and Impacts
Kestutis Arbaciauskas, Institute of Ecology, Vilnius University, Lithuania

12:00
Luncheon

Concurrent Session C

Implications for Human and Ecosystem Health: Pathogens, Toxins and Toxics

Session Chair: Russell G. Kreis, Jr., US Environmental Protectoin Agency

8:30
Reducing the Public Health Hazard from Human Pathogen Transport in Ships' Ballast Water Discharge: An Analytical Template
Gloria A. Casale, Consultant, USA

8:50
Pathogens Arriving from Ships' Ballast Water in Cartagena Bay
Silvia Rocío Rondon, Centro de investigaciones Oceanograficas e Hidrograficas, Colombia

9:10
Zebra Mussels (*Dreissena polymorpha*) and Asian Freshwater Clams (*Corbicula fluminea*) as Biological Indicators of Waterborne Contamination
Thaddeus Graczyk, Johns Hopkins University, USA

9:30
Botulism Type E in Lake Erie
Madeline J.W. Austen, Environment Canada, Canada

9:50
Are Dreissenid Mussels Responsible for the Recent Increase in Potentially Toxic Cyanobacterial Species in Lake Erie?
Anas Ghadouani, University of Waterloo, Canada

10:10
Break

10:40
Zebra Mussels as a Weapon: Can (Toxic) Blue-Algae Blooms be Conquered Using Eco-Engineering?
Anke Weber, The Netherlands Organization for Applied Scientific Research, The Netherlands

11:00
Mercury Burdens in the Chinese Mitten Crab (*Eriocheir sinensis*)
Erin Williams, US Fish & Wildlife Service, USA

11:20
High Selenium Burdens Found in Adult Female Lesser and Greater Scaup Collected on the Lower Great Lakes
Scott Petrie, Bird Studies Canada, Canada

11:40
TBD

12:00
Luncheon

Tuesday, June 10

Concurrent Session A

Control Options for Industry II

Session Chair: Robert Hester, Ontario Power Generation

1:30
Nonoxidizing Biocides for Biofouling Control
Girma Mitiku, ShellTek Inc., USA

1:50
Biological Control of Zebra Mussels with Microbial Toxin: Small-Scale Once-Through Pipe Tests
Dan Molloy, New York State Museum, USA

2:10
Peracetic Acid: Research, Control and Economics
Steven Thornton, Imperial Oil Ltd., Canada

2:30
Current Chlorination Equipment Design Strategies for Zebra Mussel Control
Walter Schajnoha, ProMinent Fluid Controls Ltd., Canada

2:50
The Application of Novel Dechlorination Technology in Meeting MISA and OWRA Regulations for Discharge of Wastewater Streams
Dan Butts, ASI Group, Canada

3:10
Break

3:40
Effectiveness and Ecotoxicological Testing of a New Elastomeric Anti-Fouling Coating Against Zebra Mussels
Yves de Lafontaine, Environment Canada, St. Lawrence Centre, Canada

4:00
Power Plant Fouling by Dreissenid Mussel Shells: A Haunting Tale of Impact from the Deep
Paul Sawyko, Rochester Gas and Electric Corporation, USA

4:20
Nine MilePoint Unit 2 Intake Tunnel Treatment and Mussel Removal
Richard F. Green, Constellation Energy, USA

4:40
***Samea multiplicalis* (Guenée, 1854): A Possible Agent In The Biological Control of *Salvinia molesta* Mitchell**
Afonso Pelli, Departamento de Ciências Biológicas - Faculdade de Medicina do Triângulo Mineiro, Brazil

Concurrent Session B

Ecosystem Impacts and Interactions II

Session Chair: Jim MacLean, Assistant Deputy Minister, Fish & Wildlife Program Review, Ontario Ministry of Natural Resources

1:30
Impact of Invasive Alien Species on Aquatic Species at Risk in Canada
Allan J. Dextrase, Ontario Ministry of Natural Resources, Canada

1:50
Rapid Ecological Change in the St. Lawrence River: A Decade of Invertebrate Invasions and Species Replacements
Anthony Ricciardi, Redpath Museum, McGill University, Canada

2:10
Potential Impacts of Zebra Mussels on Native Fishes in Lake Winnebago, Wisconsin
James P. Kirk, US Army Engineer Research & Development Center, USA

2:30
The Effect of Zebra Mussels on Benthic Invertebrate Communities in Soft Sediments
Mark A. Beekey, School of Natural Resources and the Rubenstein Ecosystem Laboratory, University of Vermont, USA

2:50
The Effects of the Hydroid *Cordylophora* sp. and Filamentous Substrate on Larval Settlement in the Zebra Mussel (*Dreissena polymorpha*)
Nadine Folino-Rorem, Wheaton College, USA

3:10
Break

3:40
What Are the Next Steps Needed to Quantify the Impacts of the Spiny Water Flea, Bythotrephes, on Temperate Lakes?
Norman Yan, York University, Canada

4:00
Impacts of Zebra Mussels (*Dreissena polymorpha*) on Foraging Success of Soft-Sediment Benthic Predators Vary Depending on Prey Position in the Habitat and Foraging Mode of the Predators
Declan J. McCabe, St. Michael's College

4:40
Population Response of Replicate Populations of White Sands Pupfish (*Cyprinodon tularosa*) to Two Exotic Species: the Western Mosquitofish and the Virile Crayfish
David Rogowski, North Dakota State University, USA

4:40
Implementation of a Bioenergetics Model for the Round Goby (*Neogobius melanostomus*)
Vickie Lee, Ontario Ministry of Natural Resources, Canada

5:00
Geographical Patterns in Biological Traits of a Sunfish Introduced to Europe: the Pumpkin-seed, (*Lepomis gibbosus*) and the Implications for Establishment Success
Gordon H. Copp, The Centre for Environment, Fisheries and Aquacultural Science, England

Concurrent Session C

Economic Impacts

Session Chair: Sharon Gross, US Fish and Wildlife Service

1:30
Economic Impacts of Invasive Species in Canada: Quantifying the Nonquantified
Hugh J. MacIsaac, Great Lakes Institute for Environmental Research, University of Windsor, Canada

1:50
Environmental and Economic Costs of Invasive Alien Species in Canada
Renata Claudi, RNT Consulting Inc., Canada

2:10
The Champlain Canal: A Conduit for Exotic Species
J. Ellen Marsden, School of Natural Resources and the Rubenstein Ecosystem Laboratory, University of Vermont, USA

2:30
Economic Impacts of Hydrilla Infestations to Angling in Lake Moultrie and Murray, South Carolina
James P. Kirk, US Army Engineer Research & Development Center, USA

2:50
TBD

3:10
Break

Policy and Management

Session Chair: Ron Pierce, Department of Fisheries and Oceans

3:40
Canada's National Code for Introduction and Transfers of Aquatic Organisms
Iola Price, Department of Fisheries and Oceans, Canada

4:00
The Millennium Challenge: The US Environmental Protection Agency's Response to Invasive Species
Henry Lee II, US Environmental Protection Agency, Coastal Ecology Branch, USA

4:20
Analysis of Canadian and American Legislation for Controlling Exotic Species in the Great Lakes
Charlotte Vásárhelyi, University of Guelph, Canada

4:40
A Case Study of Canada's Response to Aquatic Invasive Species Introductions
Francine MacDonald, Ontario Federation of Anglers and Hunters, Canada

Wednesday, June 11

Concurrent Session A

Shipping as a Vector for New Species Introductions I

Session Chair: Bivan Patnaik, United States Coast Guard

8:30
Stopping the Ballast Water Stowaways – The Global Ballast Water Management Programme Initiative
Arga Chandrashekar Anil, National Institute of Oceanography, India

8:50
Preventing Aquatic Nonindigenous Species in the United States Through Regulation, Research and Management
CDR Patrick Gerrity, United States Coast Guard, USA

9:10
The Development of the International Convention for the Control and Management of Ships' Ballast Water and Sediment
Tom Morris, Transport Canada Marine, Canada

9:30
Perceptions of Ballast Over Hull Fouling as Primary Invader Vectors
Chad Hewitt, Ministry of Fisheries, New Zealand

9:50
Ballast Water Management Practices of Foreign Flag Vessels
Anjuna Langevin, Canadian Shipping Federation, Canada

10:10
Break

10:40
The Great Lakes NOBOB Project: 38 Ships and 82 Tanks Later
Tom Johengen, University of Michigan, USA

11:00
Ballast Management and the Control of Sediment Accumulation in Water Ballast Tanks
Phil Jenkins, P. Jenkins and Associates

11:20
Do Resting Eggs in Ballast Tanks Pose an Invasion Risk?
Sarah Bailey, Great Lakes Institute for Environmental Research, University of Windsor, Canada

11:40
Ballast Tank Biofilms as "Seed Banks": Physiochemical and Microbiological Characterization
Anne E. Meyer, Industry/University Center for Biosurfaces, University at Buffalo, USA

12:00
Luncheon

Concurrent Session B

Tolerances and Physiology of Invasive Species

Session Chair: Sandra Keppner, US Fish & Wildlife Service

8:30
Effects of Temperature on Chronic Hypoxia Tolerance in the Nonindigenous Brown Mussel (*Perna perna*) from the Texas Gulf of Mexico
David W. Hicks, Texas A&M University-Corpus Christie, USA

8:50
Temperature Acclimation of Acute Upper Thermal Limits in Zebra Mussels (*Dreissena polymorpha*) from the Arkansas River, Oklahoma, Relative to that of Mussels from the Niagara River, New York
Robert F. McMahon, University of Texas at Arlington, USA

9:10
A Comparison of Metabolic Enzyme Activities and Proximate Composition of Zebra and Quagga Mussels
Ann Stoeckmann, Penn State University – Worthington Scranton, USA

9:30
Grazing of a Non-indigenous Species on Nuisance Organisms: Implications for the Use of Zebra Mussels in Biomanipulation
Miguel Dionisio Pires, Netherlands Institute of Ecology – Centre for Limnology, The Netherlands

9:50
Population Genetics and Invasive Risk Analysis of the Round Goby (*Neogobius melanostomus*) and the Tubenose Goby (*Proterorhinus marmoratus*)
Toriano A. Bowens, Cleveland State University, USA

10:10
Break

Invasions of the Sea

Session Chair: Geoffrey R.F. Hicks, Department of Conservation, New Zealand

10:40
An Overview of the Third International Conference on Marine Bioinvasions
Russell Moll, California Sea Grant College Program, USA

11:00
An Early Detection, Warning and Assessment System for Coastal Marine Alien Species
Donna D. Turgeon, NOAA/NOS/National Centers for Coastal Ocean Science, USA

11:20
Establishing a National Monitoring Programme for Marine Pests in New Zealand
Debra Wotton, Ministry of Fisheries, New Zealand

11:40
Invasive Species — Are We Winning the Management Battle?
Neil MacNair, PEI Fisheries, Aquaculture and Environment, Canada

12:00
Luncheon

Concurrent Session C

Management Case Studies

Session Chair: Dean Wilkinson, NOAA

8:30
Aquatic Nuisance Species Response in the Pacific Northwest
Stephen Phillips, Pacific States Marine Fisheries Commission, USA

8:50
Managing Invasive Species at the Portal of North America: The Louisiana State Management Plan
Alysia R. Kravitz, Center for Bioenvironmental Research at Tulane and Xavier Universities, USA

9:10
Once Established, Can Zebra Mussels Be Eliminated? A Case Study from Lake George, New York
John Wimbush, Darrin Freshwater Institute and Rensselaer Polytechnic Institute, USA

9:30
The Eurasian Watermilfoil Controversy in Lake George, NY: The Interplay Between Science, Policy and Public Concern
Charles W. Boylen, Darrin Freshwater Institute and Rensselaer Polytechnic Institute, USA

9:50
Invasion of the Aquatic Plant, *Cabomba caroliniana* in Canada. Research at Kasshabog Lake in Peterborough, Ontario
Jennifer Noel, Trent University, Canada

10:10
Break

10:40
The Oregon Spartina Response Plan
Mark Sytsma, Portland State University, USA

11:00
Long-Range Movement of Invasive Aquatic Plants Through Water Garden Trade
Kristine Maki, University of Minnesota, Department of Horticultural Science, USA

11:20
Development of Early Detection Guidance and a Model Rapid Response Plan in the Great Lakes: Issues, Need and Approach
Sarah Whitney, Great Lakes Commission, USA

11:40
River to River Project: Great Lakes United and École Instrument de Paix, Niger
Sylvie Trudel, Great Lakes United, Canada

12:00
Luncheon

Wednesday, June 11

Concurrent Session A

Shipping as a Vector for New Species Introductions II

Session Chair: Jim Bunch, Department of Fisheries and Oceans

1:30
Pathogen Organisms Arriving from Ships Ballast Water in Cartagena Bay
Silvia Rocio Rondon, Centro de investigaciones Oceanograficas e Hidrograficas, Colombia

1:50
Evaluations of Deoxygenation as a Ballast Water Treatment to Prevent Aquatic Invasions and Ship Corrosion
Mario N. Tamburri, University of Maryland Center for Environmental Science, USA

2:10
Deoxygenating Ballast Using a Dry Biomass Process: A New Technique to Treat Ballast Water to Reduce Aquatic Invasive Species Transfer
Yves de Lafontaine, Environment Canada, St. Lawrence Centre, Canada

2:30
Large-Scale Testing of Hydroclone, Screen and UV Radiation as Ballast Water Treatment Technologies
Junko Kazumi, University of Miami, USA

2:50
Break

3:20
Ship Ballast Water Treatment: The Closed-Loop Option
William Cairns, Trojan Technologies Inc., Canada

3:40
The Natural Ballast Water Exchange Method
Richard Whittaker, Teekay Shipping Canada Ltd., Canada

4:00
Kill Harmful Microorganisms in Ships' Ballast Water Using Hydroxyl Radical
Mingdong Bai, Dalian Maritime University, China

4:00
Panel Discussion: Stopping the Ballast Water Vector – Are We Close?
Moderator: David F. Reid, NOAA

Invited Panelists:
Mario Tamburri, University of Maryland, USA
William Cairns, Trojan Technologies Inc., Canada
Richard Whittaker, Teekay Shipping Canada Ltd., Canada
Richard Everett, US Coast Guard, USA
Phil Jenkins, P. Jenkins and Associates, Canada

Concurrent Session B

Control of AIS in Non-Industrial Settings

Session Chair: Robert F. McMahon, University of Texas at Arlington

1:30
Using Barriers as an Alternative Sea Lamprey Control Method: A Summary of the Design Process
Timothy Watkins, DLZ Michigan, Inc., USA

1:50
Utilization of Benthic Barrier (Mats) to Eradicate Localized Zebra Mussel (*Dreissena polymorpha*) Infestations: Laboratory Bioassays and Field Studies in Saratoga Lake, New York,
Shary Braithwaite, Darrin Fresh Water Institute and Rensselaer Polytechnic Institute, USA

2:10
Aquatic Nuisance Species: An Evaluation of Barriers for Preventing the Spread of Bighead Carp to the Great Lakes
Ronald M. Taylor, Illinois Natural History Survey, USA

2:30
Pheromone Signaling in the Round Goby
Lynda D. Corkum, University of Windsor, Canada

2:50
Break

3:20
The North America Brown Tree Snake Control Team: Keeping Brown Tree Snakes from Becoming Established in North America
Scott E. Henke, Texas A&M University Kingsville, USA

3:40
***Hydrellia pakistanae* and *H. balciunasi* – Insect Biological Control Agents of Hydrilla: Boon or Bust?**
Michael J. Grodowitz, US Army Engineer Research & Development Center, USA

4:00
Development of *Mycoleptodiscus terrestris* as a Bioherbicide for Management of the Submersed Macrophyte, *Hydrilla verticillata*
Judy Shearer, US Army Engineer Research & Development Center, USA

4:20
Use of *Euhrychiopsis lecontei* as a Biocontrol Agent for Eurasian Watermilfoil: The Response of the Native Macrophyte Community to Introduction of the Milfoil Weevil in the Swartswood Lakes, NJ
Martin Hilovsky, EnviroScience, Inc., USA

4:40
Two Pioneering Technologies for Aquatic Vegetation Management: Quantification, Application, and Relevant Examples
Douglas R. Henderson, ReMetrix LLC, USA

Concurrent Session C

Education and Outreach

Session Chair: John Gannon, International Joint Commission

1:30
Michigan's Aquatic Nuisance Species Prevention Day
Roger Eberhardt, Michigan Department of Environmental Quality, USA

1:50
Education and Outreach on Aquatic Invasive Species in Oregon: Developing a Strategy and Implementation Plan
Diane Kightlinger, Center for Lakes and Reservoirs, Portland State University, USA

2:10
Interpreting Trends in Media Coverage of Invasive Species
Alysia R. Kravitz, Center for Bioenvironmental Research at Tulane and Xavier Universities, USA

2:30
Use of a Web Site for Coordination of a Collaborative Regional Response to Control of Salvinia molesta
Kevin Fitzsimmons, University of Arizona, USA

2:50
Break

3:20
Inland Seas Education Association's Invasive Species Education Project
Colleen Masterson, Inland Seas Education Association, USA

3:40
Invasive Species Information Management in the Northeast: Laying the Foundation for an International Marine Monitoring Network
Jay Baker, Massachusetts Office of Coastal Zone Management, USA

Thursday, June 12

Concurrent Session A

Techniques for Risk Assessment

Session Chair: Alfred F. Cofrancesco, Jr., US Army Engineer Research & Development Center

8:30
Combining Allometric Parameters of Biological Processes with Recent Progress in Invasion Theory: Implications of Ballast Water Standards
John Drake, University of Notre Dame, USA

8:50
Risk Assessment for Prediction of Invertebrate Invaders in the Laurentian Great Lakes
Igor Grigorovich, Great Lakes Institute for Environmental Research, University of Windsor, Canada

9:10
A Null Hypothesis for Invasions
Robert I. Colautti, Great Lakes Institute for Environmental Research, University of Windsor, Canada

9:30
Technology Policy Implications for Ballast Water Introductions of Non-Indigenous Species
Nicole Cass, University of Delaware, College of Marine Studies, USA

9:50
Break

10:20
Quantification of Risks of Alien Species Introductions Associated with Alternative Areas for Ballast Water Exchange in the Laurentian Channel of the Gulf of St. Lawrence
Renata Claudi, RNT Consulting Inc., Canada

10:40
Invasion Kinetics of Spiny Waterflea Dispersal in Ontario
Jim Muirhead, Great Lakes Institute for Environmental Research, University of Windsor, Canada

11:00
A Risk Assessment Protocol for Non-Native Freshwater Fishes
Gordon H. Copp, The Centre for Environment, Fisheries and Aquaculture Science, England

11:20
Determining the Potential for Fish Predation to Limit Zebra Mussels (*Dreissena polymorpha*) Across Latitudinal Gradients Using Bioenergetic Models
James T. Kirk, US Army Engineer Research & Development Center, USA

11:40
Predictive Ecological Niche Modeling Using GARP: Carp Invasion in the United States
Kristina McNyset, Natural History Museum, University of Kansas, USA

12:00
Ecological Niche Modelling, New Tool for Decision Makers
Daniel Kluza, US Environmental Protection Agency, Office of Research and Development, USA

Concurrent Session B

Unauthorized Fish Introductions

Session Chair: Dennis Wright, Department of Fisheries and Oceans

8:30
Does Proximity to Roads Increase the Risk of Non-native Ornamental Fishes Being Introduced to Ponds Situated in Urban Areas?
Gordon H. Copp, The Centre for Environment, Fisheries and Aquaculture Science, England

8:50
The Effects of Bass Introductions on Lake Trout Populations in the Haliburton Highlands of Central Ontario
David M. Brown, Ontario Federation of Anglers and Hunters, Canada

9:10
Pike Removal in Lake Davis, California
Ivan Paulsen, California Fish & Game, USA

9:30
Return to the Sea: Homo Sapiens Help *Osmerus mordax* Invade Hudson Bay
William G. Franzin, Department of Fisheries and Oceans, Canada

9:50
Break

Concurrent Session C

Developing an International Response to Prevent Spread of Zebra Mussels In North America – the 100th Meridian Initiative

Session Chair: Bob Pitman, US Fish & Wildlife Service

8:30
Why a "100th Meridian Initiative"?
Bob Pitman, US Fish & Wildlife Service, USA

8:50
Risks to the West - A Western Regional Panel Objective
Erin Williams, US Fish & Wildlife Service, USA

9:10
The Aquatic Nuisance Species Program in Utah
Don Archer, Utah Division of Wildlife Resources, USA

9:30
The 100th Meridian Initiative: Database and Web Site
Dave Britton, University of Texas at Arlington, USA

9:50
Break

10:20
Interjurisdictional Responses to Reduce the Threat of Zebra Mussels and Other Aquatic Nuisance (ANS) as a Result of Lewis and Clark Bicentennial
Stephen Phillips, Pacific States Marine Fisheries Commision, USA

11:00
Preventing the Invasion of Zebra Mussels into the Connecticut River Watershed
Michelle Babione, Silvio O. Conte National Fish and Wildlife Refuge, US Fish & Wildlife Service, USA

11:20
Legislation for the 100th Meridian
Mark Sytsma, Portland State University, USA

11:40
Group-Panel Summary Discussion
Mark Sytsma Erin Williams, Don Archer, Bob Pitman

Aquatic Nuisance Species Awareness in Northern Wisconsin and the Upper Peninsula of Michigan
Margaret A. Kulwicki, University of Notre Dame, USA

A Pilot-Scale System for the Treatment of Ships' Ballast Water Using Hydroxyl Medicament
Xiyao Bia, Dalian Maritime University, China

Geographic Variation in the Genetic Variation of *Myriophyllum spicatum* Investigated by Random Amplified Polymorphic (RAPD) Markers
Charles W. Boylen, Darrin Fresh Water Institute

Zebra Mussel Control Efforts on the St. Croix National Scenic Riverway, Minnesota and Wisconsin
Byron N. Karns, National Park Service, St. Croix National Scenic Riverway, USA

Population Genetic Structure of Zebra Mussels in North America: Implications for Management
Richard F. Lance, US Army Corps of Engineeers Research & Development Center, USA

Westward Ho! Zebra Mussels on the Move
Cindy Messer, California Department of Water Resources, USA

The National Aquatic Nuisance Species Clearinghouse and Searchable Electronic Database
Charles R. O'Neill, Jr., New York Sea Grant and National ANS Clearinghouse, USA

Does Byssal Detachment Overestimate Sensitivity of Mussels to Toxic Compounds?
Sanjeevi Rajagopal, University of Nijmegen, The Netherlands

Cost Analysis of Mandatory Ballast Water Exchange in the United States
Elena Ryan, US Coast Guard, USA

A Flow-Through Field Study Demonstrating Proactive Control of Zebra Mussel Plankton by an Environmentally Friendly Starch-based Reagent
A. Garry Smythe, Stantec Consulting Services Inc., USA

Chinese Mitten Crab (Eriocheir sinensis) Reporting System and Monitoring Program in California
Erin M. Williams, US Fish & Wildlife Service, USA

Olfactory Sensory Responses of Reproductive and Non-Reproductive Female Round Gobies (*Neogobius melanostomus*) Support the Presence of Sex Pheromones
Andrea J. Belanger, University of Windsor, Canada

Isolation of Reproductive Pheromones Used by the Round Goby, a Great Lakes Invasive Fish Species
Wesley J. Arbuckle, University of Windsor, Canada

Impacts of an Invertebrate Invader on Phytoplankton Communities in Canadian Shield Lakes
Norman D. Yan, Ontario Ministry of Natural Resources, Dorset Environmental Centre, Canada

Aquatic Invasive Species in the Black Sea and Freshwater Environments in Georgia
Boris Bitsadze, Committee on Environmental Protection and Natural Resources, Georgia

Invasive Fish: A Bangladesh Perspective
Amir Hossain, Institute for Environment and Development Studies, Bangladesh

***Salvinia molesta* Growth Rates in an Urban Lake in the Plateau of Lagoa Santa, MG**
Afonso Pelli, Departamento de Ciências Biológicas - Faculdade de Medicina do Triângulo Mineiro, Brazil

Effect of Simazine on the Reproductive Behaviour and Hatching Capability of Lymnaea Peregra (Muller) Under Laboratory Conditions
M. Nazrul Islam, University of Rajshahi, Bangladesh

Invasive Species: A Destructive Force Has Met Limited Resistance – A 2002 Report of the Office of the Auditor General of Canada

Johanne Gélinas
Commissioner of the Environment and Sustainable Development, Office of the Auditor General of Canada
240 Sparks Street, Ottawa, ON K1A 0G6
T: 613-995-3708 F: 613-957-0474 E: communications@oag-bvg.gc.ca

Canada is assailed by invasive species that pose significant threats to both our ecosystems and our economy. In October 2002 the Commissioner of the Environment and Sustainable Development published a report on the issue of invasive species. The objective of this audit was to determine whether the federal government has mounted an effective response to the invasive species problem since signing the International Biodiversity Convention in 1992, and particularly since finalizing the Canadian Biodiversity Strategy in 1995.

We looked at a number of national and international plans for dealing with invasive species. In our view, to manage the problem effectively, the federal government needs to know which invasive species pose the greatest threat to Canada's environment and economy and the pathways by which they arrive, who will do what to respond, and how effective those responses have been so that corrective action may be taken as necessary. Because it is the lead department for Canada's biodiversity strategy, we looked to see whether Environment Canada on behalf of the federal government has that information or has put in place the basic tools it needs to acquire it. Since ship ballast water is the most important source of unintentional introductions of aquatic invaders, we also examined how the federal government is managing those species and that particular pathway. We looked at whether Fisheries and Oceans Canada has the basic information necessary to manage aquatic invaders and whether Transport Canada has ensured that there is adequate legislation and enforcement to control their introduction or escape into Canadian waters from ship ballast.

We found that Canada's federal government has not responded effectively to the threat posed by invasive species. Ten years after the federal commitment to prevent their introduction or to control or eradicate them, the number of invasive species in Canada continues to grow. No single department has the big picture or has the overarching authority to ensure that federal priorities are established and acted on. The federal government has not established the capability to gauge progress on its commitment to deal with invasive species and cannot demonstrate that its actions over the past decade have changed prevailing trends.

NOTES

The US Federal Government Approach to Managing Invasive Species: Clearer Focus and Greater Commitment Needed to Effectively Manage the Problem

Trish McClure
Assistant Director, Natural Resources and Environment Team, US General Accounting Office
441 G St. NW, Room 2T23, Washington DC 20548 USA
T: 202-512-6318 F: 202-512-9925 E: mcclurep@gao.gov

Harmful invasive species — nonnative plants and animals that are spreading throughout the United States — have caused billions of dollars in damage to natural areas, businesses, and consumers. In 2001, the US federal government issued a national management plan to focus attention on invasive species and coordinate a national control effort involving the more than 20 federal agencies that are responsible for managing invasives. GAO evaluated this plan and the federal government's efforts thus far to implement it. To conduct our evaluation, we assessed the content of the national management plan in light of commonly accepted performance measurement principles. We measured progress implementing the plan by evaluating the status of actions in the plan that had a start or completion date of September 2002.

While the actions called for in the US federal government's National Invasive Species Management Plan are likely to contribute to controlling invasive species, the plan lacks a clear long-term outcome and quantifiable measures of performance. Therefore, it is unclear how implementing the individual actions will move the country toward a specific outcome such as a lower number of new invasive species or reduced spread of established species by a certain amount. Federal officials responsible for the plan, recognize that there are deficiencies in the plan and are working towards improvements. We found that progress implementing the plan has been slow. As of September 2002, departments and agencies had completed less than 20 percent of the actions that the plan called for by that date, although they have begun work on others. A large majority of the members on the government's advisory committee on invasive species also believed that the pace of implementation has been slow. We found several reasons for this slow pace including delays in establishing teams that would be responsible for guiding implementation of the planned actions, the low priority given to implementation by key federal departments, and the lack of funding and staff responsible for doing the work. Some stakeholders believed that the low priority and associated lack of progress may be due to the fact that there is no legislative mandate for creating and implementing a national management plan to deal with invasive species.

United States General Accounting Office, *Invasive Species: Clearer Focus and Greater Commitment Needed to Effectively Manage the Problem*, GAO-03-1, Oct. 2002. Our full report is accessible at www.gao.gov.

NOTES

Directions in Policy and Action on Aquatic Invasive Species in the United States

Timothy R.E. Keeney
Deputy Assistant Secretary for Oceans and Atmosphere, US Department of Commerce
National Oceanic and Atmospheric Administration
Room 5804, 14th Street and Constitution Avenue, NW, Washington DC 20230 USA
T: 202-482-3567 F: 202-482-6318 E: Tim.Keeney@ noaa.gov

In the past, there has been a tendency to approach invasive species issues as individual problems rather than as generic problems, and this has affected the way in which we respond to them. Over the last decade, the United States government has moved in the direction of a more systematic approach to such issues. Of necessity, there also has been an effort to prioritize actions. Passage of legislation to address aquatic invasive species was a precursor to this trend. In 2000, the US government took a major step in addressing invasive species issues in a systematic, coordinated, and comprehensive manner when a National Invasive Species Management Plan was adopted. Since then, actions have been guided and influenced by the Plan.

One of the major foci since passage of the original legislation has been on ballast water. In the very near future, some of the issues associated with ballast water may be resolved. Whether through existing regulatory authority or through new legislation, ballast water management will be required for all ships entering US ports. We are also making substantial progress on technologies to serve as alternatives to ballast water exchange. Over the next five years, attention will be given to other pathways.

During the current Congress, the Nonindigenous Aquatic Nuisance Prevention and Control Act is due for reauthorization. The bills that have been introduced indicate that this will be a major rewrite of existing law. The proposed legislation addresses some existing gaps in legal authority such as rapid response to incipient invasions, a screening process for intentional introductions, and additional emphasis is placed on monitoring activities and research. This will contribute to a comprehensive approach to invasive species problems.

Within the Executive branch of the government, much more emphasis is being placed on efficient and effective use of resources. No one agency has the capacity or resources — financial and human — to fully address invasive species, and in some instances, lack of cooperation and coordination have resulted in resources not being effectively utilized. Last year, in the spirit of the Management Plan, federal agencies put forward a limited crosscutting budget in which priority issues were addressed. Such cooperation and coordination will not only increase on the federal level, but will also involve state and local partners.

NOTES

There's Something Weird in the Neighbourhood – Who Ya Gonna Call?! Responding to Marine Biosecurity Events in New Zealand

Chris O'Brien
Science Manager – Aquatic Environment, Ministry of Fisheries
PO Box 1020, Wellington New Zealand
T: 64 4 470 2609 F: 64 4 470 2686 E: chris.obrien@fish.govt.nz

This presentation will outline the organisational and legislative structures that underpin the management of marine biosecurity (the management of risks to the marine environment, the economy and human health) in New Zealand; then describe the role of the Chief Technical Officer - Marine Biosecurity (CTO). The CTO is a statutory position under the Biosecurity Act with wide ranging powers to manage biosecurity events. These include the ability to close areas, treat goods and equipment, and take steps to prevent the spread of organisms. The CTO has responded to a diverse range of events in recent years, including reports of "weird looking" marine creatures; false alarms about the presence of highly undesirable exotics; an undaria-fouled vessel sinking in a pristine area; large ships going aground and leaking ballast water; algal blooms; out of control sea squirts; and the unpredicted arrival and establishment of an exotic crab. The presentation will describe the approaches used to manage these events and discuss what worked and what didn't.

NOTES

Invasive Alien Species in Africa's Wetlands: Pathways, Impacts, and Solutions

Geoffrey W. Howard
IUCN - the World Conservation Union, Eastern Africa Regional Office, PO Box 68200, Nairobi, Kenya
T: 254-2-890605 X10 F: 254-2-890615 E: gwh@iucnearo.org

African wetlands are increasingly being recognised for their importance to sustainable development and biodiversity conservation. However, the direct and indirect pressures placed on wetlands to meet ever growing human needs put these systems at great risk. There is, thus, an increasing need to develop mechanisms for wetland management - both to maintain the human benefits from wetlands and to secure their biodiversity into the future. Effective management of Africa's aquatic systems has, however, been hampered by the presence of invasive alien species. The damage caused by invasive alien species to African wetlands can cost billions of dollars annually. Costs associated with the control and management of invasive species and with subsequent efforts to restore the affected ecosystems to their previous condition run into many millions of dollars per year on a national basis and even more continent-wide. The Ramsar Convention on Wetlands of International Importance together with the Global Invasive Species Programme and IUCN — The World Conservation Union, take these threats seriously and are working together to promote an understanding of wetland invasives — both from the aspect of biodiversity conservation and of human welfare. Efforts are being made to raise awareness of the existing problems and threats posed by present and future invasions, as well as provide information on the identity of invasive alien species, methods for eradication and control, and increase the availability of relevant information and technical assistance. Wetland invaders can rarely be eradicated, but experience in Africa has shown that the technical know-how exists to control many of them if they become established. However, control is always expensive and time-consuming. Furthermore there are numerous alien species that have become invasive with concomitant threats to local species and ecosystems but which are also providers of food and other products that are essential for the survival of rural communities and the reduction of poverty. Africa must work with relevant agencies and organizations to invest in prevention strategies if Africa's wetlands are going to support biodiversity and human needs in the long-term.

NOTES

The US Army Corps of Engineers Aquatic Nuisance Species Research Program

Alfred F. Cofrancesco, Jr.
US Army Engineer Research and Development Center, 3909 Halls Ferry Road, Vicksburg, MS 39180 USA
T: 601-634-3182 F: 601-634-2398 E: Cofrana@wes.army.mil

Invasive aquatic nuisance species are serious threats to US ecosystems decreasing biodiversity, impacting human health and imposing enormous costs on eradication and management efforts. They infest portions of almost all the navigable waterways in North America. In 1990 the Corps of Engineers established the Zebra Mussel Research Program to address problems specifically caused by this aquatic nuisance species. In 2002 the Corps of Engineers established a new research program, the Aquatic Nuisance Species Research Program (ANSRP) that incorporated the responsibilities of the Zebra Mussel Research Program but expanded it to include other aquatic fauna problems that impact the Corps of Engineers. Since its establishment the program has taken an aggressive position in examining the full range of aquatic nuisance species problems. The new research program will focus efforts in five general areas:

1) Introduction/dispersal
2) Control/Management
3) Species of Concern
4) Risk Assessment
5) Technology Transfer.

These focus areas are further subdivided to cover problems that have been identified for Corp of Engineers activities. Special emphasis will be placed on developing management options that will reduce negative impacts of ANS.

NOTES

Stewarding a North American Approach to Prevent the Introduction and Spread of Aquatic Invasive Species

Hans Herrmann *and Karen Schmidt*
Biodiversity Conservation Program at the Commission for Environmental Cooperation
393, rue St-Jacques ouest, Bureau 200, Montreal, QC H2Y 1N9 Canada
T: 514-350-4340 F: 514-350-4314 E: hherrman@ccemtl.org

Coastal ecosystems and the biological diversity that they support are threatened throughout North America. Multiple cumulative and often synergistic threats have already undermined the functioning of many North American marine systems. A primary constraint for both the conservation of marine species and spaces is the connectivity of marine environments, where threats such as habitat loss, climate change, pollution, and invasive species operate on large-scale processes that cannot be mitigated using traditional conservation measures.

Marine and aquatic ecosystems around the world are being transformed and degraded by non-indigenous species. These alien species affect the structure and function of the ecosystem, causing major ecological and economic implications, undermining local and regional economies, and posing new threats to human health.

Trade, globalization and increased travel between continents brings and ever increasing number of new invasives which is becoming a serious global environmental challenge. In spite of the potential international consequences of transboundary invasions, the majority of management efforts to prevent and control the spread of alien species have tended to focus nationally and rarely reach across the very political boundaries so easily traversed by the invaders themselves. Current domestic laws and official programs are insufficient to guard against this global phenomenon; no unilateral approaches can cope with the magnitude of this problem. In order to be cost-efficient and effective, activities to prevent and mitigate the impact of invasive alien species have to be based on cooperation, complementary approaches and regulations, and multi-stakeholder participation.

In the six years since the North American Free Trade Agreement (NAFTA) was implemented, total trade in North America has increased significantly. On average, trade has grown as much as five-fold between the NAFTA partners. However, among the largest increases have involved bulk transport of agricultural goods. Trade between North America and non-NAFTA partners has also expanded fueled by the World Trade Organization Uruguay Round accords. How much of that trade in goods has contributed to species moving from one ecosystem to another is unknown. However, there is no question that growing trade and travel, coupled with a more liberalized customs approach among the NAFTA countries, has meant that alien species are in motion at an unprecedented rate, thus raising the odds of aquatic alien species becoming invasive in any of North America's ecosystems.

Fortunately, Canada, Mexico and the United States all consider invasive species a substantial threat to their environment and to their economies. However, their perception of its magnitude, and consequently their domestic efforts to address this problem, are somewhat different. Given its mandate, the Commission for Environmental Cooperation (CEC) of North America is well positioned to facilitate the development and implementation of a regional approach to address the invasive species problem.

On March 28–30, 2001 the CEC convened in Montreal, Quebec, the first North American workshop to identify cooperative opportunities on "Preventing the Introduction and Spread of Aquatic Invasive Species in North America." This workshop primarily addressed intentional introductions, aquaculture and live bait, and benefited from the participation of experts and decision makers from government agencies, industry, NGOs and academia. The Montreal workshop organized by CEC in March 2001 presented the aquatic invasive species challenge as it relates to North American free markets. The purpose of the workshop was to establish a common perspective on issues concerning aquatic invasive species and consequently identify priorities for trinational and multi-sectoral collaboration.

Trade related pathways, with emphasis on ballast water, live bait, aquaculture and intentional introductions were the main themes of the workshop. Scientists, government, industry and Non-governmental Organization representa-

tives from the three countries identified priorities for cooperation within the following crosscutting themes: voluntary approaches and economic incentives, outreach and education, bio-informatics and modeling, and legal and enforcement approaches. Based on the results of their deliberations, the CEC recommends the following five priority areas to steward cooperation:

1. Identify invasive species and invasive pathways of common continental concern.
2. Develop a North American Invasive Species Information Network.
3. Develop and distribute tools for raising awareness and empowering decision-makers.
4. Identify tools to provide economic incentives to engage the industrial and economic sectors.
5. Create a regional directory of legal institutions and frameworks for the three North American countries.

NOTES

Turning the Tide: Is Aquatic Bioinvader Research Heading in the Right Direction?

Geoffrey R.F. Hicks
Manager Science and Research, and Chief Technical Officer Biosecurity, Department of Conservation
PO Box 10-420, Wellington, New Zealand
T: 64-4-471-3063 F: 64-4-471-3279 E: ghicks@doc.govt.nz

Casual analysis of scientific contributions to the 11th International Conference on Aquatic Invasive Species indicates nearly two thirds (62%) of papers were devoted to subjects of ecological and economic impacts or effects, and aspects of control, treatment or mitigation (bioinvader management). Based on the draft preliminary programme for the 12th Conference, the figures are not dissimilar. These kinds of reports are aimed at describing what happens when bioinvaders arrive in a new location, establish and then what we humans do about it. This might be described as 'reactive or curative research.' What is highlighted from this analysis, however, is a gross imbalance in terms of what might be termed 'preventative research.' By this is meant investigations designed to put us on the front foot by progressively developing our capability in scientific methodologies like pathway analysis, ecological scenario building and prediction, risk assessment and decision support systems. A similar analysis for the 11th Conference indicates less than 10% of investigations are accounted for in preventative research. Without a doubt, management of aquatic invasive species does need to know how to ameliorate adverse effects, but it is in desperate need of predictive models that maximise opportunities to prevent invaders arriving in the first place. What management does not need are endless impact studies. Investigators must reassert the notion that prevention is better (and cheaper) than cure, and the research focus should turn to building effective decision making frameworks based on good science. 'Nice to know' academic questions should be required to justify a user application, or risk being intellectually isolated from the realities of bioinvader management practice. Larger, more strategic research directions urgently beckon and some of these will be discussed.

NOTES

International Mechanisms for the Responsible Use of Introduced Species in Aquaculture and Fisheries in Inland Waters

***Matthias Halwart**, Devin Bartley and Felix Marttin*
Food and Agriculture Organization of the United Nations (FAO), Fisheries Department
Viale delle Terme di Caracalla, 00100 Rome, Italy
T: 39-06-5705-5080 F: 39-06-5705-3020 E: Matthias.Halwart@fao.org

A key aspect of the Food and Agriculture Organization of the United Nations' "Code of Conduct for Responsible Fisheries" is to help countries balance conservation and sustainable use priorities in decision-making regarding the use of alien species in aquaculture and fisheries development. Sections of the Code that relate to introduced species are scientifically underpinned by the ICES Codes of Practice on the Introduction and Transfer of Marine Organisms and the FAO Technical Guidelines for Responsible Fisheries on the Precautionary Approach to Capture Fisheries and Species Introductions. However, awareness of these international instruments and scientifically based approaches to deal with introduced species is generally lacking. We present here a framework for the responsible use of introduced species in inland waters that starts with these international obligations and mechanisms. The Food and Agriculture Organization of the United Nations Database on Introductions of Aquatic Species (DIAS) and other relevant literature were examined to provide information on alien species. Aquaculture was found to be the primary reason for the purposeful introduction of alien aquatic species and, overall, the majority of introductions for aquaculture that were assessed had positive results. National governments constituted the group most often responsible for the introductions. Ecological, social and economic mechanisms by which introduced species could impact the environment and human communities were identified; however, very little documentation existed on the actual impact of many introductions. When information is incomplete we present a precautionary approach that strives to reduce uncertainty and still allows for the responsible development of fisheries and aquaculture. The majority of the impacts reported have been from disease transmission and have mostly impacted the aquaculture industry. Improved information and monitoring and the evaluation of introductions will be necessary for informed risk assessment and decision-making.

NOTES

Global Documentation of Fish Introductions – The Growing Crisis and Recommendations for Action

Christine Marie V. Casal
FishBase Project, WorldFish Center, G.S.Khush Hall, IRRI Compound, Los Baños, Laguna 4031, Philippines
T: 63-49-536-0168 63-2-845 0563 F: 63-49-536 0202 E: c.casal@cgiar.org

Fish play an important role in the lives of people all over the world. Aside from providing 15% of total animal protein in human diets, it is also the primary source of livelihood for 35 million people (30M from Asia and 2.6 M from Africa). It is one of the major sources of livelihood and food for people from the developing world.

The increase in global population and demand for fish protein cannot be met by captive fisheries alone. Governments are turning towards aquaculture as the source of fish protein in the same way as that of agriculture providing much of the world's food from plants and terrestrial animals.

In 2000, aquaculture provided 45.7 million tonnes by weight and US$56.5 billion by value (more than half of which are finfish). The aquaculture industry has also promoted the introduction of 'aquaculture species' worldwide. Whilst this contributed significantly to aquaculture production, it has also led to the establishment of the species in local ecosystems through their escapement to the wild. In freshwater ecosystems with relatively high endemism, this has become a significant problem.

Documenting the international movement of fishes (man-made or otherwise) is one way of providing a general view of the magnitude of these movements and the existing and potential threat faced by these ecosystems. The information however is very limited and scattered in different journals and agency/project reports. Several agencies both local and international have their own databases, which provide information on the invasive species (both terrestrial and aquatic, local, regional or international in scope). The critical challenge is for consolidation, common access through data sharing and development of risk assessment and management tools.

It is proposed that there should be consolidation of information sources through the use of Internet technology, sharing of databases, etc. for introduced and invasive fish species which would allow these information to be accessed easily. The fusion of all these information sources would allow students, researchers, decision- and law-makers to access updated and reliable information for present and future programs and projects.

The experience of the WorldFish Center in documenting these phenomena through developing its FishBase information system and global partnerships is presented with recommendations for harmonizing approaches.

NOTES

Introduction to Macrofouling Control for North American Industry Using Surface Fresh Water

Renata Claudi
RNT Consulting Inc., RR 2, Picton, ON K0K 2T0 Canada
T: 613-476-7994 F: 613-476-7994 E: rnt@idirect.com

Biofouling is the generic term used for the process of deposition of living organisms and inorganic material onto all surfaces submerged in both marine and freshwater environments. The slime layer covering the surfaces of materials submerged for a period of time is produced by an assembly of microorganisms, and it is frequently referred to as "microfouling". Larger plants and animals that settle onto submerged surfaces are considered "*macrofouling*" organisms.

Macrofouling has always been a problem for industries using salt water. Barnacles, mussels, clams, tube building worms and seaweed have long plagued these industries. Macrofouling is a relatively new problem for industrial plants using fresh water and so far it is confined to only a few species of mussels and clams. However, these organisms are causing problems worldwide, from China to Europe and from North America to South America.

This presentation will review the macrofouling control options available to industry in North America using surface fresh water and discuss their applicability to various industrial processes.

NOTES

The European Experience

***Henk Jenner**, KEMA Power Generation and Sustainables*
KEMA Power Generation and Sustainables, PO Box 9035, 6800 ET Arnhem, The Netherlands
T: 26-356-3008 F: 26-351-5022 E: h.a.jenner@kema.nl

This abstract was not available at the time of printing.

NOTES

US Navy Approach to Seawater Systems Biofouling Control

Edward J. Lemieux
Center for Corrosion Science & Engineering, Naval Research Laboratory, Code 6136, P.O. Box 1739, Key West, FL 33040 USA
T: 305-293-4214 F: 305-293-4213 E: elemieux@ccs.nrl.navy.mil

Keith E. Lucas
Center for Corrosion Science & Engineering, Naval Research Laboratory
Code 6130, 4555 Overlook Ave, SW, Washington, DC 20375 USA

E. Dail Thomas II
Naval Sea Systems Command, 05M1, 1333 Isaac Hull Ave SE, Washington Navy Yard, DC 20376 USA

The US Navy has a long history in the control and prevention of the growth of biological organisms or "biofouling" both on ship hulls and interior ships spaces, namely seawater systems such as auxiliary seawater (ASW) supply and fire main systems. The leading solution to seawater system fouling control has been electrolytic halogenation, which has been utilized and evaluated by the US Navy for over 20 years and its effectiveness is reflected by its usage amongst current and future USN ship classes. This experience has lead to a large volume of practical know-how with regards to installation and operational requirements, the effects on corrosion of marine materials and the salient overboard discharge issues. The current document seeks to discuss electrolytic halogenation including, the chemical reactions, equipment design and requirements, and the methodologies for neutralization of residual oxidants prior to overboard discharge. Furthermore, the following discusses recent advances by the Naval Research Laboratory in the construction of a Ballast Water Treatment Facility in which electrolytic halogenation techniques and equipment may be validated on a land-based, shipboard-volume scale, as well as any other ballast water treatment technique available form industry.

NOTES

Fish Diversion Systems for Invasive Species Applications

Paul H. Patrick
Kinectrics Inc., 800 Kipling Avenue, Toronto, ON M8Z 5S4
T: 416-207-6277 F: 416-207-6094 E: paul.patrick@kinectrics.com

New introductions of invasive fish species into the Great Lakes continues to cause significant damage to the aquatic ecosystem, and also to the economies that depend on it. Over the past two decades, extensive work has been done to develop technology solutions to deter fish from water intakes used by various industry sectors. Kinectrics has been involved in a number of such developments for the energy industry, particularly at facilities located on the Great Lakes and associated major waterways. The fish protection technologies that have been developed fall into two broad categories depending on their mode of action:

• *Exclusion Systems* (Behavioural and Physical Systems). Behavioural systems rely on the responses of fish themselves to stimuli such as light and sound. Physical systems physically block fish passage (usually in combination of low flow velocities). and;

• *Diversion Systems* that divert fish to bypasses for return to a safe release location. Diversion systems can use both behavioural and physical techniques.

Over 20 technologies have been developed, and the potential of each of these technologies for diverting and or guiding invasive target species will be addressed.

NOTES

High-Power Electron Beam Treatment: A Control Technology for Invasive Species

David Bierling, ***Peter McIntyre,*** *and Leslie Olson*
Department of Physics, Texas A&M University, College Station, TX 77843 USA
T: 979-845-7727F: 979-845-2590 E: p-mcintyre@physics.tamu.edu

Don D. Smith
Accelerator Technology Corp., 207 Dellwood, Bryan, TX 77801 USA

We report the development of a new technology for high-power electron beam treatment of water. One unit can support a throughput of up to one million gallons/day, delivering sufficient dose to kill all species except viruses. The treatment does not add any chemicals to the water, and produces a temperature rise of <0.1 °C.

The new accelerator technology offers an economically feasible, environmentally sound treatment for control of invasive species and for other water applications.

NOTES

Effects of a Pulse-Power Electric Field on Settlement Rates of Zebra Mussels on Structure and the Presence of the Asiatic Clam in Sediments

A. Garry Smythe *and Cameron L. Lange*
Stantec Consulting Services Inc., 140 Rotech Drive, Lancaster, NY 14086-9755 USA
T: 716-759-1200 F: 716-759-1489 E: gsmythe@stantec.com

Andrew C. Miller
United States Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180 USA

Several small field studies were conducted by the authors since the mid 1990s to evaluate the potential for an environmentally safe, pulse-power electric field to control the zebra mussel (*Dreissena polymorpha*). Although the study-sites, conditions and electrical parameters have varied (many of the variations in the latter unintentional), the system including the basic power supply and its control-cards (by Megapulse), the electrode test-cell and flow through systems have been similar. However, in each study there was an obvious effect indicating control of fouling (settlement), though the overall level of control also varied (42%, 78%, 84%, 88% and 93%). The research began to focus on the reason for the variability and it was suspected that, among other factors it might be a combination of planktonic mussel-size and variation in the electric field strength within the test-cell.

A study-season was needed in which the electrical and environmental parameters remained relatively constant throughout the study, with a concurrent settlement event where mussel settlement densities in control samples were adequate for determining effect in treatments. In conjunction, a set of parameters that could be considered as base-line for future studies was needed. A base-line was developed related to factors common to most past studies and was part of the study-plan for the 2001 study initiated in the early fall and ending in December, 2001. The study was conducted using Mississippi River water at an Entergy facility in Westwego, LA.

In the 2001 study, the Megapulse unit ran flawlessly and total settlement numbers for all control settlement plates was just over 100 mussels indicating a settlement density of slightly less than 408 mussels/m^2. Overall control was 65%, while a comparison of paired treatment and control settlement plates with more than 10 mussels on a plate indicated base-line control ranging from approximately 27% to 88%. Data also indicated zebra mussels in the control were slightly smaller than those in the treatment, supporting previous assumptions. Data also suggests that there is no recovery with time and the base-line effect is probably mortality-or-nothing. A comparison of the Asiatic clam (*Corbicula* spp.) in sediments of the treatment and control tanks indicated the base-line parameters provided 64% control of the clam.

Results of the 2001 study will be used to develop study plans and equipment configurations that can improve the system performance. The study methods, results and potential future efforts will be discussed.

NOTES

Application of the Ever Clear™ Filter for Removing Mussels at Industrial Water Intakes

***Paul H. Patrick**, L. Gonzalez and B. Sim*
Kinectrics Inc., 800 Kipling Avenue, Toronto, ON M8Z 6C4
T: 416-207-6277 F: 416-207-6094 E: paul.patrick@kinectrics.com

Zebra mussels and more recently, quagga mussels, have caused both operational and maintenance problems at power plants and other industrial water users on the Great Lakes. Control options typically include chemical based mitigation strategies but there are still environmental concerns with the continual release of chemicals to the environment. Recognizing this, Kinectrics, has carried out extensive work to develop new technologies such as micro-filtration as potential non-chemical control options. This work has utilized research carried out at facilities in Ontario over the last two decades, and has culminated in a product known as the Ever Clear™ filter. This filter has been the subject of full-scale field trials at Ontario Hydro Generating Stations including Nanticoke GS and Sir Adam Beck in 1999–2000, with the primary objective of removing mussels from the water intakes. Further improvements have been made to the filter, which include a new micro mesh design, advanced spray nozzles and unique back-washing capabilities, and the filter is now available for commercial application. Technical data will be presented on both the biological and engineering performance of the filter system.

NOTES

State Fish Hatcheries and Invasive Species Don't Mix

Marcus N. Allhands
Amiad Filtration Systems, PO Box 261, Lewisville, IN 47352 USA
T: 805-377-8580 F: 765-987-7843E: allhands@kiva.net

The Edgar Weed Fish Culture Station in Grand Isle, VT is the newest of five stations operated by the Vermont Fish and Wildlife Department for the purpose of restocking fish in public waters. The design of the hatchery took advantage of a cold deep-water inlet and a warm shallow-water inlet in Lake Champlain for efficient water temperature control. Since the hatchery specializes in trout and salmon, water temperature is a critical factor. Up to 42 000 m^3 (11 million gallons) of water per day must be treated from Lake Champlain to meet the requirements of the fish culture station. Problems began when zebra mussels began invading the shallow-water inlet. Water withdraw from the shallow-water inlet was terminated. Able to use only the deep-water inlet, large unexpected costs were incurred in heating the cold water to reach optimum growing conditions for the hatchery. To allow the use of both water inlets for efficient temperature control required the design of a filtration system with mechanical stainless steel weavewire screens rated at 40 microns absolute to assure the prevention of any life forms of zebra mussel from infiltrating the hatchery. The system had to be flexible to allow variable amounts of water from each inlet to be filtered and mixed. The system had to be fully automatic and could not come off-line for cleaning. It had to handle a maximum flow rate of 2000 m^3/hr (8800 gpm). The designed system consisted of nine 10" automatic self-cleaning screen element pressure filters operating at 1.4 bars (21 psi). The multi-option control board allowed any number of filters to operate at any one time and any proportional combination of flows from the two lake inlets. The system has been operating flawlessly since November 1996 with no zebra mussels detected within the hatchery proper. The presentation will describe the operation of this filtration technology and the details of the complete system for the Edgar Weed Fish Culture Station as designed and installed.

NOTES

Efficacy of Ozone for Control of Macrofouling in an Industrial Raw Water System

Ron Larocque
Hankin Ozone Systems Limited, 690 Progress Avenue, #12, Scarborough, ON M1H 3A6 Canada
T: 416-439-7860 F: 416-439-6806 E: ronaldl@hankinozone.com

This presentation will discuss the three years of performance and efficacy of a large-scale, industrial, ozone generation system. The system was installed to prevent macrofouling and microfouling in piping carrying raw Lake Ontario water in a once-through cooling circuit.

To date, the system has controlled all manner of fouling and continues to perform well technically. The short half-life of ozone results in water discharge that has very low levels of ozone with no mortality to trout fingerling in test tanks.

Ozone represents a viable alternative to other oxidizing and non-oxidizing chemicals for control of biofouling and is considered a superior alternative from an environmental impact point of view.

NOTES

Recent Trends of Nonindigenous Aquatic Species in the Temperate Regions of North America

Amy J. Benson
US Geological Survey, Florida Caribbean Science Center, 7920 NW 71st Street, Gainesville, FL 32653 USA
T: 352-378-8181 x 306 F: 352-378-4956 E: amy_benson@usgs.gov

New introductions continued to be discovered through dedicated surveys and other related activities from 1999 to the present. During this same time period, existing populations of introduced organisms have expanded their ranges with little help from humans. There are many examples of these over the past several years. In the Great Lakes, the ruffe was collected in Lake Michigan for the first time last year. Several adult bighead carp have been collected in Lake Erie and in the Ohio River. In the Mississippi River, the silver carp and bighead carp populations have increased significantly. The round goby continues to move down the Illinois River towards the Mississippi River. Zebra mussels were found for the first time in the state of Virginia. Snakeheads were discovered in a private pond in Maryland. The Asian clam has been found in two new states in New England and a population of tench appears to be established in Lake Champlain. On the east coast of the United States, lionfish began appearing in relatively large numbers and the Asian shore crab was collected in Maine. These new introductions and range expansions, as well as many others, have been reported or published. Unfortunately due to the immense volume of biological surveys and observations each year in North America, there is no doubt important information has gone unreported and unpublished.

NOTES

Patterns and Mechanisms of Species Replacement among Invasive and Native Amphipods

Michelle E. Palmer *and Anthony Ricciardi*
Redpath Museum, McGill University, 859 Sherbrooke St. West, Montreal, QC H3A 2K6 Canada
T: 514-398-4806 x3191 F: 514-398-3185 E: michelleelaine@hotmail.com

Facilitative interactions among invading species may magnify their impact on native species. We conducted field experiments to examine patterns and mechanisms of replacement of a native amphipod, *Gammarus fasciatus*, by an invasive amphipod, *Echinogammarus ischnus*. Both species use interstitial spaces of exotic dreissenid mussels (*Dreissena polymorpha* and *Dreissena bugensis*) as microhabitats. However, *Echinogammarus* has become the dominant amphipod on mussel-covered substrate in recent years, apparently because of a stronger interaction with *Dreissena*. *Echinogammarus* occurs naturally with *Dreissena* in Europe, and may be adapted to living in dreissenid mussel beds. *Gammarus*, by contrast, has no evolutionary experience with epifaunal mussels.

Sampling of benthic substrates shows that *Echinogammarus* achieves higher densities than *Gammarus* on mussel-covered rocks but not on rocks covered by algae or fine sediment. To test the hypothesis that *Echinogammarus* uses mussel beds as refugia against predation more effectively than *Gammarus*, an in-situ experiment was conducted at a site in the St. Lawrence River near Montreal, where all three taxa are present. Artificial substrates (cement bricks) covered with attached *Dreissena* shells were deployed with and without predator-exclusion cages. After a period of several weeks, *Echinogammarus* became the dominant amphipod on the experimental bricks, but there was no significant difference between predator-access and predator-exclusion bricks for either *Echinogammarus* or *Gammarus* abundances. Thus, differential susceptibility to predation does not explain relative amphipod abundance at this site. *Echinogammarus* may be exploiting other resources associated with mussels (e.g., biodeposits).

NOTES

Competition Between Exotic and Indigenous Gammarids

Mariëlle van Riel *and Gerard van der Velde*
Department of Animal Ecology and Ecophysiology, Faculty of Science, University of Nijmegen
Toernooiveld 1, 6525 ED Nijmegen, The Netherlands
T: 31-24-365-2625 F: 31-24-365-2134 E: mvriel@sci.kun.nl

Abraham bij de Vaate
RIZA Institute for Inland Water Management and Waste Water Treatment, PO Box 17, 8200 AA Lelystad, The Netherlands

Invaders of the River Rhine are nowadays mostly Ponto-Caspian macro-invertebrates, which enter the Rhine from the Danube River through the Main-Danube canal since 1992. One of the most dominant invader species at the moment is *Dikerogammarus villosus*, a stone dwelling amphipod that inhabits the River Rhine since 1995. This species is the largest amphipod species in the Rhine River and is a strong predator. Since *D. villosus* invaded the River Rhine, the densities of other macro-invertebrates, especially those of other amphipods are on the decline. This may be due to predation and competition for food and space by closely related species.

Interspecific competition between various indigenous and exotic gammarid species for substrate was tested in microcosm experiments in the laboratory. The substrates used reflected those occurring in the River Rhine and allowed the species to chose for various degrees of shelter. The influence of densities and sequence of colonization on the outcome of the competition experiments were also studied.

NOTES

Do Bio/Ecological Traits Promote the Invasion Success of the Amphipod *Dikerogammarus villosus* in Western Europe?

Simon Devin
Laboratory of Biodiversity and Ecosystem Functioning, University of Metz
Metz, France.

Dikerogammarus villosus, an amphipod species of Ponto-Caspian origin, is the latest successful invader of Western Europe hydrosystems, and is suspected to reach in the next future North America, and particularly the Great Lakes. It has invaded the Moselle River (Northeastern France) in 1999, following a rapid spread along the Danube and Rhine Rivers. Although it has rapidly become a major component of macrobenthic assemblages, and the dominant amphipod species, its biology, ecology and population dynamics remain poorly documented.

We studied *D. villosus*' population dynamics over a one-year period in a recipient ecosystem. With the data obtained from the one-year study, growth-related life-history traits of *D. villosus* were investigated using a growth-at-length model. For the first time, distinctive models were established for a natural population and for sex-separated individuals of a freshwater gammarid. The model allowed for an assessment of different biological traits such as life span, the age of sexual maturity, the potential number of generations per year and the growth rate depending on environmental conditions. *D. villosus* exhibits several traits facilitating its establishment. The species reaches sexual maturity early, at six mm in length, and produces three reproductive peaks, though the species reproduces all year long. These three peaks reflect the multivoltine character of the species. The population was consistently characterized by a female-biased sex ratio and exhibit one of the highest fecundities of Western Europe amphipods. Growth-rate differences between males and females are coherent with biological processes such as the allocation of energy for reproduction (when temperatures are above 12 °C) and the ability to survive winter conditions.

The ecological characteristics of *D. villosus* were investigated at mesoscale on a station of the Moselle River. The study shows that this amphipod is able to colonize a wide range of substrate types, thus all freshwater ecosystems are potentially threatened. Rivers which dominant substrates are cobbles and tree roots along the bank could exhibit particularly high density of *D. villosus*. A relationship exists between the substrate particle size and the length of the individuals, and a spatial segregation according to the length has been shown, allowing this species to limit the intraspecific competition between generations while facilitating its reproduction. A strong association appear between *D. villosus* and other Ponto-Caspian species, such as *D. polymorpha* and *C. curvispinum*, fitting with the invasional meltdown theory. *D. villosus* occurrence could severely impact Coenagrionidae, *Calopteryx splendens*, *C. curvispinum* and *G. tigrinus* populations, as their spatial niches strongly overlap at mesoscale.

A comparison with biological characteristics of different fresh or brackish-water gammarids highlighted the invasive specificities of *D. villosus*.

NOTES

Dikerogammarus villosus, a Ferocious Omnivore

Dirk Platvoet
Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam
PO Box 94766, 1090 GT Amsterdam, the Netherlands
Tel: 31-20-5256288 Fax: 31-20-5255402 Email: platvoet@science.uva.nl

Jaimie T.A. Dick
School of Biology and Biochemistry, Queen's University of Belfast, 97 Lisburn Road, Belfast BT9 7BL Northern Ireland

The Ponto-Caspian amphipod *Dikerogammarus villosus* Sowinsky, succesfully invaded western Europe during the last decade, replacing at least one native counterpart. It is very likely that this species will find its way into other regions like the N. American Great Lakes. One of the factors that contributes to the success of this species is its feeding behaviour. In general, gammaridean amphipods are assumed to be detritivorous herbivores. Little is known about predation in this group. To investigate this feeding behaviour, *D. villosus* was filmed while being offered various food items. Apart from detritus and living plant matter, a range of invertebrates were eaten and predation seems the dominant feeding mode. The unusually large second antennae play a major role in catching prey. The film shows several examples of highly developed prey catching techniques in this amphipod. We predict this invader will have serious consequences for the biodiversity of invaded regions.

NOTES

Ecological Impacts of Invasive Aquatic Amphipods (Crustacea): Patterns, Mechanisms and the European Lesson for North America

Jaimie T.A. Dick
School of Biology & Biochemistry, Queen's University Belfast
Medical Biology Centre, 97 Lisburn Road, Belfast BT9 7BL, Northern Ireland
T: 44-28-90272286 F: 44-28-90236505 E: j.dick@qub.ac.uk

Invasive amphipods are increasingly recognised as having diverse impacts on aquatic ecosystems, with a number of new invasives, such as the Ponto-Caspian *Dikerogammarus villosus*, predicted to invade and impact upon the N. American Great Lakes. Here, I outline field and laboratory studies that indicate invasive amphipods, as compared with native species, can drastically alter aquatic communities. For example, in Ireland, the invasive *Gammarus pulex* significantly reduces community diversity and richness, and dramatically alters community structure, when compared to the native *G. d. celticus.* This occurs through direct mechanisms, such as predation by the invader on other macroinvertebrates, and indirect mechanisms, such as alteration of prey microdistribution and the facilitation of fish predation. Further, I present data on the influence of parasites on mediating interactions among invasive and native amphipods. For example, acanthocephalan and microsporidian parasites can significantly alter the strength of interspecific interactions, such as intraguild predation, and thus alter the outcome and/or impact of invasive species. Finally, I review the research efforts of a number of European scientists and institutions in the field of invasive amphipods, such that lessons can be learned by our counterparts in North America. For example, collaboration among UK, Dutch and French laboratories point to severe impacts on aquatic ecosystems of *Dikerogammarus villosus*, leading to our warning that this potential new invasive of N. America should be mitigated against.

NOTES

An Analysis of the Exotic Aquatic Invasions in the Rhine Delta

***Gerard van der Velde**, Ivan Nagelkerken and Sanjeevi Rajagopal*
Department of Animal Ecology and Ecophysiology, University of Nijmegen
Toernooiveld 1, 6525 ED Nijmegen, The Netherlands
T: 31-24-3652621 F: 31-24-3652134 E: gerardv@sci.kun.nl

Abraham bij de Vaate
Institute for Inland Water Management and Waste Water Treatment, P.O. Box 17, 8200 AA Lelystad, The Netherlands

Alien species in the inland water bodies in the Dutch Rhine delta are known since the Middle ages. However, alien aquatic invasions in the area are booming during the last century caused by increasing anthropogenic activities. Introductions and escapes caused 65% of the aquatic invasions, canals connecting rivers 25% and invasions from the seaports by seagoing ships 10%. Their origin is mainly North America, Eastern Europe and Asia. These figures are different for plants, macroinvertebrates and vertebrates. Invasions took place in all types of habitats.

The figures were analysed and underlying causes of the success of various invaders discussed in relation to abiotic conditions in various habitats in order to get an overall picture of the cause of these invasions and their impacts on various ecosystems.

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Dreissenid Mussels in Eastern Lake Ontario and the Upper St. Lawrence River: A 10-Year Follow-Up Survey of Navigational Buoys

David Bruce Conn
School of Mathematical & Natural Sciences, Berry College, Mount Berry, GA 30149 USA
T: 706-236-1756 F: 706-238-7855 E: bconn@berry.edu

Denise A. Conn and Joshua D. Conn
North American Scientific Enterprises (NASCENT), Monteagle, TN 37356 USA

From 1990–1992, we conducted extensive surveys of navigational buoys in the eastern Lake Ontario/Upper St. Lawrence River regions, to monitor the initial spread of dreissenid mussels through the area. Our results during those three critical years demonstrated that multiple points of introduction had occurred, which differed with respect to species composition. The population of exclusively *Dreissena polymorpha* downstream near Cornwall, Ontario was gradually overtaken by mixed populations of *D. polymorpha* and *Dreissena bugensis* moving into the river from Lake Ontario. Observations on co-occurring native organisms during the initial dreissenid invasion of the area raised some questions regarding potential negative impacts on native benthic biota.

From 1998–2002, we received anecdotal reports from various river observers of reduced numbers of adult caddisflies (Insecta: Trichoptera), known locally as "shadflies", in spring and summer mating swarms. Thus, we initiated a 10–year follow-up survey of navigational buoys to gather information on changes in populations of dreissenids and native benthos over the intervening years. Special attention was given to aquatic larvae of the caddisfly *Brachycentrus incanus*, hydropsychid caddisfly larvae, amphipod crustaceans, and gastropod molluscs. The fieldwork was conducted from 27–31 December 2002, examining buoys retrieved at the end of the navigational season and dry-docked at Prescott, Ontario and Ogdensburg and Massena, New York.

During 2002, the numbers of dreissenids in eastern Lake Ontario were much higher than in the St. Lawrence River; dreissenids were absent from many river buoys. *Dreissena polymorpha* was predominant in Lake Ontario and the uppermost part of the river (i.e., Thousand Islands region). However, *D. bugensis* was predominant in the St. Lawrence River below the Thousand Islands to Cornwall, Ontario. Both dreissenid species exhibited a bimodal size distribution, especially in the Thousand Islands region; all individuals of one cohort were under 5 mm in length, whereas all in the other were more than 15 mm in length. This probably reflects two separate spawning events during the 2002 summer reproduction season. Size distributions among Lake Ontario populations were more uniformly distributed, possibly reflecting more heterogeneous origins for the colonizing mussels in the lake. These results differ from those in 1992, when *D. polymorpha* predominated throughout the river; it was the only species on river buoys during that period, although *D. bugensis* was common on deeper benthic substrates during that same period, as determined by extensive SCUBA-based observations.

Comparison of data from 1990-1992 with those from 2002 provides no conclusive evidence of reduction in caddisfly numbers during the 10-year period. However, baseline data are inadequate for drawing firm conclusions. Because of the tremendous ecological importance of the caddisflies, further study is needed. Thus, we are planning a multi-year follow-up, beginning in summer 2003, to develop better baseline data and look specifically at the population trends in native St. Lawrence River caddisflies, amphipods and gastropods. This program will include scuba-based work in summer, coupled with surveys of retrieved navigational buoys each December for several years.

We gratefully acknowledge the assistance of Chuck Lemaire, Canadian Coast Guard, and Greg MacKinnon, US Dept. of Transportation.

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Ponto-Caspian Crustaceans in the Inland Waters of Lithuania: Introduction, Current Distribution, Factors for Survival and Impacts

Kęstutis Arbačiauskas
Institute of Ecology, Vilnius University, Akademijos St. 2, Vilnius LT-2600, Lithuania
T: 370-527-29241 F: 370-527-29257 E: arbas@ekoi.lt

Dispersal of Ponto-Caspian mysids and amphipods in the drainage basin of the Baltic Sea is at least in part associated with introduction of these animals into adjacent freshwater bodies. Lithuania was the first place in the Baltic Sea basin, where these non-native species were introduced 40 years ago, with intention to improve the feeding conditions for fish. Ponto-Caspian amphipods *Pontogammarus robustoides*, *Obesogammarus* crassus and *Chaetogammarus warpachowskyi*, and *mysids Paramysis lacustris*, *Limnomysis benedeni* and *Hemimysis anomala* were introduced into the Kaunas Water Reservoir located on River Nemunas, during 1960-1961. These crustaceans established sustainable populations there. Ponto-Caspian species naturally via River Nemunas dispersed to the Curonian Lagoon, and successfully acclimatized in this lagoon. Later intentional transplanting of non-native species to over 100 lakes and two other water reservoirs was tried. Recently, sustainable populations of Ponto-Caspian amphipods and mysids inhabit these two water reservoirs. Non-native amphipods and mysids were also found in 6 and 8 lakes, correspondingly. Current distribution suggests that Ponto-Caspian amphipods can establish sustainable populations only in large mesotrophic lakes, while mysids could also survive in large and open eutrophic lakes. Both groups of these crustaceans can also live in well-drained lakes. Among Ponto-Caspian amphipods and mysids, *P. robustoides* and *P. lacustris* exhibited the largest tolerance to lake environment. The limiting factor for long-term survival of non-native amphipods in lake ecosystems of Lithuania likely can be oxygen concentration in the littoral during winter, i.e. under the ice cover. For relations with native malacostracans, current studies indicate that *P. robustoides* and *Gammarus lacustris* or *G. pulex* do not coexist. In the habitats suitable for Ponto-Caspian amphipod *P. robustoides*, this amphipod excludes the native species. However, the mechanism of interaction between non-native and native species remains unexplored. There are also indicators suggesting that Ponto-Caspian mysid *P. lacustris* could have a negative effect on the native glacial relict mysid *Mysis relicta*. The pilot study of the trophic positions of non-native and native mysids in the food web of a lake using stable isotope and gut content analysis, however, did not indicate the overlap in diet between mysid species of different origin. In the habitats suitable for their survival, Ponto-Caspian species usually develop abundant populations, and become an important food source for fish. Ponto-Caspian mysids are mainly consumed by fish fry, while amphipods are included also in diet of older and larger fish. The environmental impacts of non-native Ponto-Caspian crustaceans will be discussed.

NOTES

Reducing the Public Health Hazard from Human Pathogen Transport in Ships' Ballast Water Discharge: An Analytical Template

Gloria A. Casale
2 Kiva Loop, Sandia Park, NM 87047 USA
T: 505-286-8567 F: E: Gloria_Casale@msn.com

Hugh H. Welsh
Port Authority of New Jersey, 11 Mansion Terrace, Cranford, NJ 07016 USA

The biohazards associated with the international transport of pathogens, organisms that produce disease in plants or animals, as well as non-indigenous species have recently been revealed and documented. [1]In response, a number of ballast water management plans have been promulgated. However, none of these plans have satisfactorily addressed the problems of pathogen transport. We propose a template to characterize, identify and quantify the public health hazards posed by pathogen transport, develop methods for tracing origins and destinations of human pathogens and develop acceptable standards ballast tank effluent. The ultimate outcome is to propose standards for ballast water discharge, which can be incorporated into federal and international regulations.

Currently, many scientists around the world are testing the ballast water of vessels entering their navigable waters for pathogens. We conclude that continuing testing and tracking are essential steps in defining the biohazard associated with the transport of pathogenic microorganisms in ballast water. Available data are limited to the following: pathogens are transported in the ballast water of ships; these organisms pose a biohazard to many species including humans, marine mammals, fish, mollusks and shell fish. In addition, these organisms are able to survive in ballast tanks despite adverse conditions.

Increased scientific knowledge is essential before adequate solutions can be formulated. The development of resolutions will require techniques that rely on collaboration between scientific and legal experts.

To date, regulations in effect have not successfully mitigated the health hazard caused by pathogens in discharged ballast water. The current voluntary compliance of mid-ocean at-sea-exchange can pose a substantial threat to the crew and cargo of ships in heavy seas. Contaminated ballast deposited into high-speed ocean currents will rapidly disburse biohazardous material. Also, pathogenic organisms in ballast exchanged just beyond the navigable waters could be carried to beaches, shellfish beds and other food sources by wind and tides. These concerns are especially relevant to algal blooms. Importantly, recent investigations imply that many ships do not comply with voluntary at-sea-exchange of ballast water.

An additional impediment to sound protective measures aimed at investigating ballast water biohazards is that several legislatures have passed statutes that are not based on current scientific knowledge and technology. They therefore present a complex regulatory labyrinth, which invites noncompliance and interferes with international trade.

Current research is developing mechanisms that will decrease the numbers of pathogens and invasive macro species in ballast water. Until more data are available and analyzed the nature and extent of the ballast water biohazard cannot be clearly defined. These data are essential before appropriate ballast water treatment standards can be developed, codified and enforced. This template will provide insights to encourage the development of scientifically sound ballast water biohazard mitigation technology.

[1]Casale, GA and HH Welsh. The International Transport of Pathogens in Ships' Ballast Water. Journal of Transportation Law, Logistics and Policy. 65(1): 79-87.

Pathogen Organisms Arriving from Ships' Ballast Water in Cartagena Bay

Silvia Rocío Rondon
Centro de investigaciones Oceanograficas e Hidrograficas (CIOH), División de Estudios Ambientales
Escuela Naval Almirante Padilla, Isla Manzanillo, Cartagena, Colombia
T: 57-5-6694104 F: 57-5-6694297 E: srondon@cioh.org.co

Considering that several species of bacteria, plants and animals can survive in the ballast waters transported by ships and the role of ballast water as a mean for propagating bacteria casing epidemics, a research study was initiated to identify the species of organisms present in this type of waters arriving in the Cartagena Bay. The analysis of pathogen bacteria, phytoplankton and zooplankton was made in the samples from ballast water tanks.

The samples were screened for the presence of Vibrio cholerae selecting yellow colonies on TCBS agar and performing the arginine dihydrolase and esculin hydrolysis tests using purified isolates. Isolates giving negative reactions in the both of the tests was presumptively considered V. Cholerae.

This research is the first study in ballast water in Colombia and is the first step to adequately define of the nature and extent of the problem in the country to develop in the future control and preventive measures.

NOTES

Zebra Mussels (*Dreissena polymorpha*) and Asian Freshwater Clams (*Corbicula fluminea*) as Biological Indicators of Waterborne Contamination

Thaddeus K. Graczyk
Department of Molecular Microbiology and Immunology, School of Hygiene and Public Health, Johns Hopkins University
Baltimore, MD 21205
T: 410-614-4984 F: 410-955-0105 E: tgraczyk@jhsph.edu

D. Bruce Conn
Berry College, Mount Berry, GA, USA, Martha Berry Highway, Mount Berry, GA 30149 USA

David J. Marcogliese and Yves De Lafontaine
Environment Canada, St. Lawrence Centre, 105 McGill Street, 7th Floor, Montreal, QC H2Y 2E7 Canada

Asian freshwater clams (*Corbicula fluminea*) and zebra mussels (*Dreissena polymorpha*) accidently introduced into North America became established in many freshwater habitats. *Cryptosporidium parvum* and *Giardia duodenalis* are zoonotic intestinal protozoan parasites transmitted via water. Oocysts of *Cryptosporidium parvum* were identified in zebra mussels from the St. Lawrence River, Quebec. Approximately 67 oocysts per ml of hemolymph and 129 per gram of soft tissue of zebra mussels were recovered. The pathogen retention rates measured under laboratory conditions for *C. fluminea* were 1.9×10^5 oocysts of *C. parvum*, and 0.6×10^5 *G. duodenalis* cysts per clam. Six-week laboratory exposure of *D. polymorpha* and *C. fluminea* to both parasites seeded daily at concentrations reported from surface waters demonstrated efficient removal of *C. parvum* oocysts and *G. lamblia* cysts by both bivalve species. The number of parasites in mollusk tissue progressively increased in relation to the concentration of waterborne contamination, and decreased after cessation of the contamination. Zebra mussels and *Corbicula* clams can recover and concentrate in their tissue human waterborne pathogens and therefore can be used for sanitary assessment of water quality.

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Botulism Type E in Lake Erie

Madeline J. W. Austen *and Sandra George*
Environment Canada, Ontario Region, 867 Lakeshore Rd., Burlington, ON L7R 4A6 Canada
T: 905-336-4476 F: 605-336-6272 E: madeline.austen@ec.gc.ca

Jeff Robinson
Canadian Wildlife Service, Environment Canada, 465 Gideon Drive, P.O. Box 490, London, ON N6P 1R1 Canada

Helen Domske
New York Sea Grant, 207 Jarvis Hall, SUNY, Buffalo, NY 14260-4400 USA

Eric Obert
Pennsylvania Sea Grant, Penn State Erie, 1000 Glenhill Farmhouse, Behrend, Erie, PA 16563 USA

Grace McLaughlin
USGS National Wildlife Health Center, 6006 Schroeder Road, Madison, WI 53711 USA

Ward Stone
NYSDEC-Wildlife Pathology Unit, 108 Game Farm Road, Delmar, NY 12054 USA

In recent years (1999-2002), there have been numerous fish and bird die-offs on Lake Erie. Many of these die-offs have been related to the botulism bacteria, *Clostridium botulinum*, and more specifically to Type E botulism. Type E botulism is caused by one of the seven neurotoxins (A-G) that can be produced by *C. botulinum*, and is largely restricted to fish-eating birds in the Great Lakes. Most of the current Type E botulism outbreaks have occurred in Lake Erie.

Botulism outbreaks in Lake Erie are of particular concern due to the possible role aquatic invasive species (e.g., round gobies and dreissenid mussels) may play in the disease cycle, the die-offs of large numbers of waterfowl over the past four years, and the occurrence of botulism outbreaks in adjacent lakes (Lake Huron and Lake Ontario) in 2002. There is the possibility of population-level effects in certain species (e.g., lake sturgeon, common loons) if die-offs continue to affect these species in the future. In Ontario, die-offs of large numbers of migratory birds occurred for the fourth consecutive year with 1,000 dead loons reported in one die-off in November 2002; the majority (700) of these loons were reported on beaches at Long Point. Along the New York shoreline of Lake Erie, some estimates of die-offs include 8000 waterbirds (red-breasted mergansers, ring-billed gulls, common loons, and herring gulls) in November 2000; approximately 5,400 waterbirds and several thousand gull mortalities suspected in western New York region in 2001; and over 6519 bird mortalities documented from New York shoreline of Lake Erie in 2002. In New York in 2002, the greatest mortalities were for long-tailed ducks (4774 individuals), red-breasted mergansers (451 individuals), and common loons (419 individuals). New York totals recorded for 2002 were much higher than for 2001 (706) and 2000 (1110).

Information will be provided on the botulism cycle, signs of avian botulism in animals, locations of recent botulism outbreaks, wildlife species involved in die-offs, potential linkages of botulism outbreaks to the spread of aquatic invasive species, and ongoing botulism research in Lake Erie.

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Are Dreissenid Mussels Responsible for the Recent Increase in Potentially Toxic Cyanobacterial Species in Lake Erie?

Anas Ghadouani *and Ralph E.H. Smith*
Department of Biology, University of Waterloo, 200 University Avenue West, Waterloo, Ontario, N2L 3G1 Canada
T: 519-888-4567 x 3773 F: 519-746-0614 E: aghadoua@sciorg.uwaterloo.ca

In recent years, there has been a growing concern about Lake Erie trophic status as phytoplankton biomass seems to have increased during the last couple of years. There have also been more reports on the occurrence of potentially toxic cyanobacterial species such as *Microcystis aeruginosa*. It has been stipulated that the observed changes in phytoplankton communities may have been caused by the dreissenid mussel invasions of Lake Erie. Small-scale studies have shown that zebra and/or quagga mussels can increase nutrient availability and hence increase phytoplankton growth and possibly promote a selective growth of toxic cyanobacterial species. In the summer of 2002, we have used a new *in situ* fluorometric method (Fluoroprobe) to estimate phytoplankton biomass and composition during several cruises on Lake Erie. Although highly variable, phytoplankton biomass was generally high across the entire lake but was especially high in the Central and the Western basin. This is consistent with recent reports stating that Lake Erie may be becoming as productive as it was in the early 1980s. High biomass of potentially toxic cyanobacterial species, mainly *Microcystis aeruginosa* and *Anabaena* spp., were found at several locations in the Western and Central basins and may be indicative of the recent eutrophication problems in Lake Erie. Results from the 2002 summer cruises will be discussed and potential explanations proposed.

NOTES

Zebra Mussels as a Weapon: Can (Toxic) Blue-Algae Blooms Be Conquered Using Eco-Engineering?

Anke Weber *and M. Smit*
The Netherlands Organization for Applied Scientific Research – Institute of Environmental Sciences
Energy Research and Process Innovation (TNO-MEP), PO Box 57, 1780 AB Den Helder, The Netherlands
T: 31-223-638804 F: 31-223-630687 E: a.weber@mep.tno.nl

In eutrophic water systems where stratification occurs during the warm summer months (toxic) algal blooms present a regular annoyance for wildlife and tourists.

In order to prevent these blooms, an experiment was carried out testing a new eco-technological water purification method: the mussel filter. But what is Eco-engineering? Eco-engineering seeks to use ecological principles in technological solutions, for example, the application of certain qualities of macro-organisms of groups of macro-organisms in solving specific (environmental) problems. This zebra mussel filter is one of these applications.

This idea of the filter is based on the fact that algal blooms can only flourish if there are sufficient nutrients in the water. If, therefore, the amount of nutrients can be reduced the bloom might be prevented. Using the filtering capacity of *Dreissena* (zebra mussel) is one possibility to diminish the concentration of particle-bound nutrients and consequently reduce or even prevent an algal bloom.

In this presentation the example of eco-engineering is illustrated for the case of the Steenbergse Vliet, a dutch river with a high nutrient load originating from the surrounding agricultural land. Every year thick layers of blue algae form and cost plenty of fish and bird lives. The prototype mussel filter was tested there for 6 month. First results indicate that 27% of the present phosphate and 43% of the present nitrate could be removed in the pilot construction, a promising result for the effective reduction of the basis of algal blooms. Conclusions of the project are presented focussing on the applicability of the system in natural and semi-natural water systems. Finally, we will present the optimised filter construction as it will be installed in the Steenbergse Vliet during the summer of 2003.

NOTES

Mercury Burdens in Chinese Mitten Crab (*Eriocheir sinensis*)

Erin Williams
US Fish and Wildlife Service , 4001 N. Wilson Way, Stockton, CA 95205-2486 USA
T: 209-946-6400 x 321 F: 209-946-6355 E: Erin_Williams@fws.gov

Clifford Hui
US Geological Service, University of California, 1 Shields Avenue, Davis, CA 95616-5224 USA

Deborah Rudnick
University of California Berkeley, 201 Wellman Hall, Berkeley, CA 94720 USA

First discovered in San Francisco Bay in 1992, the Chinese mitten crab has become firmly established in the watersheds of San Francisco Bay and its tributaries, the Sacramento and San Joaquin rivers, and their tributaries. Mitten crabs have been shown to collect chromium, iron, lead, mercury, and zinc in their tissues (Bianchini and Gilles 1996; Che and Cheung 1998). Mitten crabs may accumulate metals and organic toxins when rearing in streams with high bioavailability.

The California Department of Health Services analyzed 36 adult crabs in 2000 for mercury, arsenic, selenium, and DDT metabolites. These crabs, collected at the Tracy fish screening facility, were migrating downstream from a variety of upstream locations, none of which locations is known. All substances were below health warning threshold levels, but the mercury test conducted was not sensitive enough to detect threshold levels of mercury.

The US Fish and Wildlife Service, US Geological Service, and University of California Berkeley, collaborated in a study to determine the relative mercury burdens in mitten crabs of Guadalupe River and its adjacent tributaries in south San Francisco Bay. Guadalupe River drains the watershed of the now-retired New Almaden mercury mine, which was once the largest producer of mercury in North America. It is anticipated that the crabs in Guadalupe will have higher mercury burdens than crabs in neighboring creeks. The level of mercury burdens and crab distribution among the streams with and without mercury contamination will provide an indication of the potential toxic threat posed to wildlife and human consumers of these crabs. Crab predators include humans and likely grebes, gulls, herons, egrets, striped bass, sturgeon, raccoons, and river otters. In summer 2002 the team collected 29 crabs to sample for mercury contamination. Sample methods and preliminary mercury contamination results will be discussed.

NOTES

High Selenium Burdens Found in Adult Female Lesser and Greater Scaup Collected on the Lower Great Lakes

Scott Petrie
Long Point Waterfowl and Wetlands Research Fund, Bird Studies Canada, PO Box 160, Port Rowan, ON N0E 1M0 Canada
T: 519-586-3531 F: 519-586-3532 E: Spetrie@bsc-eoc.org

Since the mid-1980s the combined continental population of Lesser (*Aythya affinis*) and Greater Scaup (*Aythya marila*) (hereafter scaup) has declined substantially. Several hypotheses for this decline have been tabled, and a number of these are presently being tested. One cause for concern has been the substantial increase in the number of scaup staging on portions of the lower Great Lakes and the fact that these birds have switched to a diet dominated by zebra mussels (*Dreissena polymorpha*) (Hamilton and Ankney 1994, Petrie and Knapton 1999). Zebra mussels are filter feeders and they incorporate and accumulate sediment and water-associated contaminants into their tissue more readily than do native Great Lakes bivalves (de Kock and Bowmer 1993, Fisher et al. 1993, Swackhamer and Skoglund 1993, Brieger and Hunter 1993). Contaminants can subsequently be passed up the food chain to waterfowl that consume these mussels. For instance, the results of feeding captive Tufted Ducks (*A. Fuligula*) contaminated zebra mussels included: high contaminant levels in liver tissue; reduced kidney weights; disturbed vitamin A production; behavioural deviations; fewer and smaller eggs per nest; accumulation of organochlorines in eggs; reduced hatchability; lower chick weights and female mortality at the start of the breeding season (de Kock and Bowmer 1993). Therefore, consumption of large quantities of zebra mussels on the lower Great Lakes may be contributing to the continental scaup decline.

In response to this concern, the Long Point Waterfowl and Wetlands Research Fund (LPWWRF) embarked on a study of Lesser and Greater Scaup contaminant burdens, nutrient reserve dynamics and dietary intake on the lower Great Lakes in 1999. LPWWRF collected scaup on lakes Ontario, Erie and St. Clair during the fall of 1999 and spring of 2000 (n = 800 birds). All birds have been dissected and are presently being analyzed for 1) types and levels of contaminants and metals within liver tissue; 2) body condition (levels of fat, protein and ash); and 3) dietary intake.

Selenium was identified by Custer and Custer (2000) as being in an elevated to potentially harmful range in Lesser Scaup collected in western Lake Erie and Lake St. Clair in 1991 and 1993. Because they did not study Greater Scaup, and their Lesser Scaup sample included only three adult females, we decided that selenium burdens in scaup staging on the lower Great Lakes warranted more attention.

Our initial analysis involved spring collected (early March through early May) adult female Lesser and Greater Scaup. All birds analyzed were collected from pairs and flocks. Female Lesser Scaup had selenium levels ranging from 1.8-56.4 µg/g dry weight. Birds from Lake Ontario had the highest selenium burdens (øa = 22.0 µg/g, range = 19.9-56.4, n = 10), those from Lake Erie the lowest burdens (øa = 12.7 µg/g, range = 9.2-25.0, n = 10) and Lake St. Clair birds had intermediate burdens (øa = 16.7 µg/g, range = 1.8-32.9, n = 10), although between-lake differences were insignificant (P = 0.160). Greater Scaup had selenium burdens ranging from 19.0-59.7 µg/g (øa = 28.4 µg/g, n = 13, samples from all three lakes combined) and these were significantly higher than found in Lesser Scaup (P = 0.005). Levels in both Lesser and Greater Scaup are cause for concern, because concentrations in livers above 10 µg/g (dry weight) in ovulating Mallards is associated with reproductive impairment, and because concentrations above 33 µg/g (dry weight) can be considered harmful to the health of a bird (Heinz 1996). One hundred percent of adult female Greater Scaup and 77% of adult female Lesser Scaup that we have analyzed had selenium levels above the level at which reproductive impairment could be expected. Preliminary results indicate that there are positive correlations between body fat and collection date (r= 0.614, P = 0.001), body fat and selenium burdens (r= 0.499, P = 0.002), and selenium burdens and collection date (r= 0.294, P = 0.128) in spring collected Lesser Scaup. This suggests that scaup are acquiring selenium and body fat while staging on the lower Great Lakes in spring. In contrast, PCB and p,p ¡ - DDE levels were found to be generally below Lowest Observed Effect Levels (LOEL) established for other bird species. What is selenium and why is considered to be a problem? Selenium is a semi-metallic trace element occurring naturally in some soils; its also a byproduct of smelting operations, and other industrial activities. Although selenium is nutritionally

required by birds in small amounts, it is highly toxic in slightly greater amounts. Selenium concentrations build quickly in tissues when birds are introduced to a selenium-contaminated diet (Heinz et al 1989). Selenium is also quickly excreted from the body when removed from a selenium-contaminated diet; females use the egg as a route of selenium excretion (Heinz et al 1989). Heinz et al. (1989) fed female mallards 10 µg/g of selenium. After six weeks, selenium in the liver averaged 7.4 µg/g wet weight (approximately 28 µg/g dry weight). However, selenium in the liver had nearly peaked after about one week. Selenium can also increase rapidly in aquatic organisms, particularly in filter feeders such as zebra mussels. Field studies show that benthic invertebrates can accumulate 20 to 370 µg/g of selenium and still maintain stable, reproducing populations (Lemly 1996). These levels are somewhat alarming as Heinz et al. (1989) showed that reproduction in Mallards was impaired at a dietary concentration of 9 ug/g, with the effects threshold falling between 4 and 9 ug/g. Lemly (1996) recommended 3 µg/g as the toxic threshold for selenium in aquatic food-chain organisms consumed by fish and wildlife.

During 2002-03, LPWWRF will be analyzing additional Lesser and Greater Scaup samples, including birds collected during fall. We will also be analyzing tissues that were collected from scaup on Lake Ontario (Canadian Wildlife Service) prior to zebra mussel introduction, as well as zebra mussels themselves. This should enable us to determine if there is in fact a link between selenium burdens in scaup on the lower Great Lakes and zebra mussel consumption. We hypothesize that while selenium inputs to the lower Great Lakes may not have increased substantially over the past 15 years, zebra mussels, through filter feeding and bioaccumulation, have concentrated selenium in their tissues, thereby increasing the availability of this semi-metallic trace element to certain species of waterfowl. Due to the large numbers of Lesser and Greater Scaup staging on the lower Great Lakes, where zebra mussels are readily available, this may be contributing to the continental decline of the combined populations of scaup.

NOTES

Nonoxidizing Biocides for Biofouling Control

Girma Mitiku *and Allan Michael*
ShellTek, Inc., 3 Electronics Drive, Danvers MA 01923 USA
T: 978-646-9235 F: 978-646-9236 E: mitgirm@hotmail.com

Dom Cataldo and Peter Van Voris,
BioGuard, 8220 West Gate Blvd., Kennewick WA 99336 USA
T: 509-372-2104 F: 509-375-2533 E: dac@bioguardtech.com).

The bioactive ShellTEK 103 has been proven effective in control of juvenile and mature zebra mussels. The needs or application for mussel control include: clearing of mussel populations within water intakes, and subsequent protection from recolonization; clearing of mussels in stationary impoundments; and killing of mussel juveniles in the ballast waters of both sea-going pleasure craft and commercial vessels prior to entry to international ports.

This natural product contained in ShellTEK 103, while effective, requires that specific treatment criteria be met to be target specific and treatment efficacy. Treatment criteria involve three basic aspects, these include: 1) effective dispersion to different types of water bodies/applications; 2) transport of the bioactive to target sites (location of mussels); and 3) optimization of entrainment/contact with juveniles and adults.

While each targeted application have its own specific requirements for efficacy and use, all systems currently developed rely on a type of chemical effervescence, which is activated on contact with water and allows For rapid or timed dispersion of the actives. All components of these releasing devices are natural and biodegradable, and provide no secondary risk concerns. The product provides nontoxic alternatives to oxidizing biocides (for micro - and macrofouling), thus offering environmental benefits while maintaining or improving performance.

NOTES

Biological Control of Zebra Mussels with Microbial Toxin: Small-Scale Once-Through Pipe Tests

***Daniel P. Molloy**, Denise A. Mayer and Kathleen T. Presti*
Division of Research & Collections, New York State Museum, 51 Fish Hatchery Road, Cambridge, NY 12816 USA
T: 518-677-8245 F: 518-677-5236 E: dmolloy@mail.nysed.gov

Small-scale, service-water tests in artificial pipes within a hydropower station demonstrated that exposure to bacterial strain CL0145A can result in high zebra mussel mortality. Strain CL0145A is a North American isolate of *Pseudomonas fluorescens* — a ubiquitous, soil-water, Gram-negative rhizobacterium, and a US patent for the use of this strain for Dreissena control has been issued. Zebra mussels die from a biotoxin naturally present within CL0145A cells, not from infection. Tests were conducted using service water (mean 23°C) within a New York Power Authority hydro station on the Mohawk River (Crescent, NY). Four acrylic pipes (L x D - 25 x 5 cm) were each seeded with 100 mussels (9mm mean length) on the day prior to treatment and then were treated at ca. 80 ppm with CL0145A cells throughout a 6-hr period while maintaining a constant water flow rate (4L/hr) within each pipe. Identical untreated control pipes with 100 mussels (3 replicates) were also maintained. Following the 6-hr treatment period, mussels continued to be held in pipes and received fresh service water (23°C) for 14 days. The entire test was conducted twice over a one-month period. Mean (±SD) mussel mortalities in these two tests were 97.2 (±1.5)% and 99.7 (±0.6)%. In contrast, mean (±SD) mussel mortalities in untreated control pipes were, respectively, 2.0 (±1.7)% and 3.7 (±1.5)%. The significance of these test results in relation to the overall goal of the commercialization of strain CL0145A as a zebra mussel control agent will be discussed.

NOTES

Peracetic Acid: Research, Control and Economics

Steven Thornton
Imperial Oil Limited, PO Box 3022, Sarnia, ON N7T 7M1 Canada
T: 519-339-2381 F: 519-339-4436 E: steve.a.thornton@esso.com

Dan Butts
ASI Group, 250 Martindale Road, St. Catharines, ON L2R 7R8 Canada

The use of peracetic acid as a credible method of zebra mussel control has been studied in depth since the early 1990s. This paper will present a cumulative analysis of all results in terms of effectivess, safety/handling issues and economic viability as compared to the mainstream method of control, chlorination.

NOTES

Current Chlorination Equipment Design Strategies for Zebra Mussel Control

Walter Schajnoha *and Garth deBruyn*
ProMinent Fluid Controls Ltd., 490 Southgate Drive, Guelph, ON N1H 6J3
T: 519-836-5692 F: 519-836-5226 E: WalterS@prominent.ca

Sodium Hypochlorite has been used in many Zebra Mussel Control strategies for many years as it is a proven, reliable and readily available solution for the prevention of this invasive species. The design of a reliable injection system incorporates many criteria to deal with the material compatibility concerns as well as the unique fluid properties of sodium hypochlorite. The focus of this paper is to summarize the recent design developments that contribute to the selection and implementation of a working strategy for sodium hypochlorite addition. The paper summarizes materials of construction currently used in the sodium hypochlorite addition system and the benefits of each. This paper also outlines methodologies for the correct fabrication of the chemical addition package and provides insight to the various components and industry standards that should be considered in the overall system design.

NOTES

The Application of Novel Dechlorination Technology in Meeting MISA and OWRA Regulations for Discharge of Wastewater Streams

Dan Butts
ASI Group, 250 Martindale Road, St. Catharines, ON L2R 7R8 Canada
T: 905-641-0941 F: 905-641-1825 E: dbutts@aquatic.com

Increasingly stringent limits for effluent contaminant loading, and Municipal/Industrial Strategy for Abatement (MISA) regulated non-toxic discharge compliance points have challenged both municipal and industrial dechlorination operations. Traditional chemical methods present problems with depletion of critical parameters such as pH or dissolved oxygen, as well as generating health and safety concerns over toxic decomposition products. Recent work has been focused on deriving user-friendly, non-chemical means for dechlorination. This application work presents details of the preliminary investigation and first commercial trial of novel, chemical agents applied in a commercial utility for resolution of discharge limits for an aqueous wastewater stream.

Ascorbic acid (AA), a common organic compound with very strong affinities for free and combined chlorine, has recently made headlines as a viable, potentially cost-competitive solution for meeting MISA and OWRA discharge requirements for wastewater streams. While often used, and documented, in other geographical areas, primarily in municipal potable water supplies, there is no previous record of AA as a dechlorinating agent or any previous Certificate of Approval issued in the Province of Ontario. Initial consultation with the Ministry of the Environment (MOE) indicated a keen interest based on results found in the literature search; obvious benefits cited were ease of handling, fewer health and safety concerns, and less impact on the environment.

In January 2002, a joint study was initiated with a major utility into the use of ascorbic acid in turnkey chemical dosing packages to meet discharge compliance limits while a new treatment facility was constructed. The goal was to demonstrate the effectiveness on a small scale while monitoring critical MISA parameters and acute toxicity prior to designing the full-scale systems and obtaining the necessary approvals.

Pilot testing in-house determined the stoichiometric ratio (2.6 to 2.98 g:g TRC) and rate of reaction for static and dynamic (flow-through) system dechlorination models. Experiments were run using both bulk solid and aqueous solutions (5wt% to 30wt% AA) to determine if there were any effects on the dechlorinating properties with the change in isomers from L- to D-ascorbic acid. Subsequent tests identified an effective 'maximum solution age' of 28 days, useful in sizing the containment and inventory for large systems, and toxicity tests on the actual influent and treated effluent streams of interest. A final battery of tests were performed to simulate 'worst case' scenarios of pump failures, containment ruptures and extreme overdosing in order to ascertain the impact on the effluent (dissolved oxygen, pH, acute toxicity). All data confirmed the effectiveness of a flow-paced, aqueous solution of optimal concentration for the dechlorination of the waste stream.

The inactive drainage (IAD) is a moderate flow system (400 to 1200 USGPM per unit, eight units in service) that collects influents from various system drains, yard and roof drains, floor drains and bearing seal water. The effluent is toxic on a seasonal basis primarily as a result of residual chlorine used to limit biofouling and control zebra mussels. The main requirement was to be non-toxic under MISA guidelines by July 1, 2002. The OWRA limit for discharge or residual chlorine is 10 ppb; the utility had set an internal goal of achieving 2 ppb in the final effluent. Typical concentrations of TRC in the IAD influent ranged (historic) from a few hundred ppb to over 10 ppm, and other contaminant species were present at close-to-toxic levels periodically (copper, hydrazine). These values were used to size the dosing panels and provide rough control parameters for setting the pump stroke/rate to achieve the dechlorination.

Results of the in-house studies were presented to the client and the MOE four (4) months after the initiation of the work. An amendment to the station C of A for the use of ascorbic acid as a dechlorinating agent metered by stand-alone panels, a first in the Province, was received in approximately five (5) months after the start of the project. Monitoring requirements were very strict for the first months, with "good" results equalling reduced monitoring later

in the season. The effluent was to be non-toxic at all times, with DO not to fall below 4, pH not to fall below 6 and residual AA not to exceed 10 ppm as measured by colorimetric strip comparison. Installation of eight stand-alone systems was completed within one month of receipt of the C of A, allowing several weeks for commissioning and validation of lab numbers prior to the enforcement of compliance goals. All systems have been operating efficiently since mid-June.

This project was started in early January of 2002, with a turn-around time of less than six (6) months. All research, experimentation, system parameter determination, securing a chemical supply, negotiating and obtaining an amended C of A for a novel technology, fabrication, delivery and installation of system components and training of operations staff were on incredibly tight deadlines, requiring extensive co-operation.

This project contributed several new ideas to the wastewater study area, particularly in the area of effluent dechlorination for elimination of residual toxicity in the Province of Ontario:

- Successful testing, design/build and supply of the first large-scale industrial/municipal use of AA as a dechlorinating agent prior to effluent discharge to a surface water body
- The first MISA acute-toxicity study on AA as a dechlorinating compound, with all in-house testing requirements reviewed by the MOE and duplicated testing at the MOE laboratories to confirm the initial data
- First to supply bulk, 15wt% aqueous solution of AA in the Province
- Validation of the dependence on L- and D- isomers and solution age allowed larger totes to be used for bulk supply, improving the logistics for chemical delivery and reducing handling requirements on site
- Verification of previously-reported stoichiometric ratios for dechlorination with AA
- Obtained both a stationary and roving C of A for industrial/municipal dechlor systems utilising AA
- First impact study on effect of AA overdosing on pH of highly-buffered lake waters, DO level and residual AA
- Supply of a safer, reliable dechlorinating compound at a cost three to five times that of more traditional compounds, with recovery based on reduced capital equipment and containment

NOTES

Effectiveness and Ecotoxicological Testing of a New Elastomeric Anti-Fouling Coating Against Zebra Mussels

Yves de Lafontaine
Environment Canada, Centre Saint-Laurent,, 105 McGill St., Montreal, QC H2Y 2E7Canada
T: 514-496-5025, F : 514-496-7398 E: yves.delafontaine@ec.gc.ca

Michel DeBlois
M.D. Technologies, 1257 chemin Royal, Saint-Laurent, Ile d'Orléans, QC Canada

Experiments were conducted to test the anti-fouling effectiveness and the ecotoxicological response of a new elastomeric coating against zebra mussels (*Dreissena polymorpha*). *In situ* experiments using multi-plate samplers treated with the coating and control untreated samplers were immersed in the St. Lawrence River during two consecutive years for testing colonization rate by zebra mussels. Ecotoxicological testing of the leachates of the treated coating was achieved by bioassays under laboratory conditions. The elastomeric coating significantly reduced colonization of zebra mussels by >85% after 1 year and the effectiveness was similar during the second year of immersion. The treated plates were also relatively free of sponges and other fouling organisms, suggesting that the anti-adhesive property of the coating would be effective against a large variety of freshwater organisms. Results from five bioassays indicated that the leachate from the elastomeric coating did not induce a toxic response. Our results suggest that this new coating may represent a useful alternative for controlling zebra mussels fouling on submerged structures.

NOTES

Power Plant Fouling by Dreissenid Mussel Shells: A Haunting Tale of Impact from the Deep

Paul M. Sawyko
Rochester Gas and Electric Corporation, 89 East Avenue, Rochester, NY 14649 USA
T: 716-771-2706 F: 716-771-2781

Most impacts attributable to dreissenid mussels focus upon their life processes of infestation and growth, however impacts may also occur long after they die, as a result of the substantial number of empty shells which accumulate on the bottom of a waterbody over time. At Rochester Gas and Electric's Russell Station, located on Lake Ontario's southern shore 1.5 mi west of the Genesee River, such dreissenid shells are commonly brought into the station within the cooling water flow from the Lake, and have occasionally created significant problems by overwhelming travelling screens and clogging condenser tubes, forcing units offline for condenser cleanings.

After being stirred up from the Lake bottom and entrained into the power plant intake, mussel shells are brought into the forebay where they settle out and accumulate on the forebay floor. The travelling waterscreens remove some shells on a regular basis during their normal operation. Not known as being particularly effective in removing shells, these screens nonetheless removed an estimated 11 tons of shells at Russell Station during 1999, a year of heavy shell fouling. Once in the forebay, the shells can easily get around, under, or through the screens and deposit on the downstream side of the screen, just prior to circulating cooling water pumps. During annual scheduled unit outages, volumes in the range of 7 cubic yards of shells are removed from within this pumpwell area. During storm conditions the amount of shells being brought into the plant increases sufficiently to be picked up by the pumps and taken to the condensers, where they quickly clog the condenser tubes, requiring the unit to be taken offline and the tubefaces to be cleaned.

While a qualitative relationship between storm events and shell entrainment is generally known, weather conditions which could accurately predict such fouling have not been identified. However, in the course of reacting to this problem during station operation, three databases have developed that can provide some quantitative information concerning the frequency and magnitude of this fouling problem: 1) a continual recording of condenser backpressures which provides an indication of when a condenser requires cleaning; 2) a log of Work Orders for performing such cleanings which may also provide comment concerning the fouling material; and 3) station impingement studies which include quantification and identification of debris material collected upon the travelling screens. During 2000, RG&E also placed current and turbidity meters in the Lake to monitor these parameters, determine conditions which precipitated dreissenid fouling, and determine opportunities for modifying the intake to reduce such impacts.

Unfortunately for this investigation, 2000 was a rather calm year, and therefore no information regarding current direction or velocity during storm conditions was obtained. From the Plant impingement information available, it was found that 1999 was the year of heaviest shell fouling, followed by 2002, 2001 and 2000, in that order. A review of the condenser cleaning and impingement databases clearly show the difference between the relatively stormy year of 1999 versus the calm lake conditions experienced in 2000.

NOTES

Nine Mile Point Unit 2 Intake Tunnel Treatment and Mussel Removal

Richard F. Green
Constellation Energy, PO Box 63, Lycoming, NY 13093 USA
T: 315-349-4239 F: 315-349-7442 E: Richard.Green@nmp.cn.com

Nine Mile Point Unit 2 is a 1230 MW Nuclear plant located on Lake Ontario. Zebra mussels have been in the Nine Mile area since the early 1990s. To control the mussel population, Nine Mile has been injecting non-oxidizing biocides into their intake tunnels and then throughout the plant piping systems. As population densities of mussels have increased in the local area, the numbers of mussel shells coming out of the tunnels following an injection has increased. The treatment methodology, of the tunnels and subsequent cleanup of the mussel shells that are released from the tunnels will be reviewed.

NOTES

Samea multiplicalis (Guenée, 1854): A Possible Agent In The Biological Control of *Salvinia molesta* Mitchell

Afonso Pelli
Departamento de Ciências Biológicas - Faculdade de Medicina do Triângulo Mineiro, Rua Frei Paulino, 30 - Uberaba/MG CEP 38025-180 Brazil
T: 55-34-3318-5424 E: apelli.oikos@mednet.com.br

Francisco A. R. Barbosa
UFMG–ICB, P.O. Box 486, CEP 30161-970, Belo Horizonte, MG Brazil

Eliot Taylor
Broadland Environmental Services Ltd. First Floor, Wensum House,103 Prince of Wales Road, Norwich, Norflok NR1 1DW UK

Biological control programmes of *Salvina molesta* were indicated in the 1960s and satisfactory results were reached in the middle 80s. Simultaneously, control and eradication programmes of this species, based on herbicides and physical methods have been carried out successfully, in spite of the high costs. Studies of the arthropod fauna associated with *Salvinia* spp. in six localities in Brazil showed the occurrence and possibility of *Cytobargous sp.*, *Samea multiplicalis* and *Paulinia acuminata* as three possible agents in the biological control. Collections and experiments were carried out at Olhos d'Água Lake, from February 1991 to March 1992, with the purpose of estimating the harm caused by *S. multiplicalis*, as well as identifying its feeding preference relating to the age of the *S. molesta* parts, besides developing a simulation model to estimate the population growth of *S. molesta*, in the presence or not of *S. multipllicalis*. The experiments indicated the existence of a preference for new leaves in 90% of the observations. Three densities of "large" *S. multiplicalis* larvae were tested in tanks in the *S. molesta* liquid growth rates, as well as the effect in the accumulation of biomass. These experiments showed that in the densities under experimentation, *S. multiplicalis* reduces significantly the *S. molesta* liquid growth and biomass. In the Olhos d'Água Lake, *S. multiplicalis* consumes approximately 12% of the annual production of *S. molesta*. In cold environments, or in those with little nitrogen, *C. salvinae* does not become established. In these circumstances, *S. multiplicalis* could be used as an option in the biological control of *Salvinia*. *S. multiplicalis* associated with physical and chemical control processes, could maintain the *Salvinia* populations in controlled densities, avoiding bigger loss.

NOTES

Impact of Invasive Alien Species on Aquatic Species at Risk in Canada

Alan J. Dextrase
Ontario Ministry of Natural Resources, Box 7000, Peterborough, ON K9J 8M5 Canada
T: 705-755-1786 F: 705-755-1788 E: alan.dextrase@mnr.gov.on.ca

Nicholas E. Mandrak
Great Lakes Laboratory for Fisheries and Aquatic Sciences, Department of Fisheries and Oceans, 867 Lakeshore Road, Burlington, ON L7R 4A6 Canada

This abstract was not available at the time of printing.

NOTES

Rapid Ecological Change in the St. Lawrence River: A Decade of Invertebrate Invasions and Species Replacements

Anthony Ricciardi
Redpath Museum, McGill University, 859 Sherbrooke St. West, Montreal, QC H3A 2K6 Canada
T: 514-398-4086 Ext. 4089 F: 514-398-3185 E: tony.ricciardi@mcgill.ca

Beginning in the early 1990s, a series of ecological transformations occurred in the St. Lawrence River as a result of successive species invasions. The first transformation resulted from zebra mussels (*Dreissena polymorpha*) densely colonizing the upper St Lawrence River and rapidly altering the benthos. In the presence of zebra mussels, invertebrate communities on hard substrates became dominated by gammarid amphipods (*Gammarus fasciatus*) and deposit-feeding organisms, while species adapted to smooth substrate (e.g., pleurocerid snails and net-spinning caddisflies) were severely reduced. At several sites, populations of native unionid mussels that had survived decades of environmental stressors were extirpated within only five years following zebra mussel invasion.

More recently, another Ponto-Caspian species, the quagga mussel *Dreissena bugensis*, has increased in abundance and has taken over as the dominant mollusc at a site where zebra mussels had maintained high densities since 1990. At the same time, a Ponto-Caspian amphipod *Echinogammarus ischnus* has replaced *Gammarus fasciatus* as the dominant benthic crustacean at several sites—a change that could affect the diets of yellow perch and other important forage fishes.

Some of these events are explained by empirical models and experiments, while others, thus far, seem to defy explanation. Such frequent disruptions confound water quality evaluations that rely upon benthic invertebrate surveys.

NOTES

Potential Impacts of Zebra Mussels on Native Fishes in Lake Winnebago, Wisconsin

***James. P. Kirk**, K. Jack Killgore and Larry G. Sanders*
US Army Engineer Research and Development Center, Environmental Lab
3909 Halls Ferry Road, Vicksburg, MS 39180- 6199 USA
T: 601-634-3060 F: 601-634-2398 E: Kirkj@wes.army.mil,

Ron M. Bruch and Art F. Techlow
Wisconsin Department of Natural Resources, 625 East County Road Y, Suite 700, Oshkosh, WI 54901 USA

This study will evaluate the response of the fish community in Lake Winnebago, Wisconsin to an increasing infestation of zebra mussels. Sampling in Lake Winnebago since the mid 1980s (prior to zebra mussel infestation) has provided baseline information describing growth, condition, and abundance of the fish community. Preliminary analysis suggests substantial variability in the abundance of target species, e.g., freshwater drum *Aplodinotus grunniens*, and guilds representing different trophic levels of the fish community. Samplers are being used to evaluate the yearly density and size distribution of zebra mussels as well as their cumulative densities over time. During 2001, an early stage of the zebra mussel infestation, density estimates ranged an order of magnitude from approximately 150/m^2 to almost 10 000/m^2; the presence of submersed aquatic vegetation apparently decreased attachment of zebra mussels. Zebra mussels collected during 2002 have yet to be analyzed but the densities appear to be much greater than 2001. This study, because of intense monitoring of the fish community, should characterize impacts to native fishes and thus be of use to other regions where zebra mussels are likely to spread.

NOTES

The Effect of Zebra Mussels on Benthic Invertebrate Communities in Soft Sediments

Mark A. Beekey *and J. Ellen Marsden*
School of Natural Resources and the Rubenstein Ecosystem Lab, University of Vermont
Aiken Centre, Burlington VT 05405 USA
T: 802-859-3086 F: 802-859-3089 E: mbeekey@zoo.snr.uvm.edu

D.J. McCabe
Biology, St. Michael's College and the Rubenstein Ecosystem Lab of the University of Vermont
Colchester VT USA

Colonization of soft sediments by zebra mussels dramatically alters the physical structure of the benthos. Zebra mussels form thick continuous mats across soft substrates, and deposit large amounts of waste that degrade water quality. Research has demonstrated that zebra mussels facilitate benthic invertebrate communities on hard and soft substrates. In general, invertebrate diversity and abundance increase with the exception of native mussels and clams. Zebra mussels provide refugia and a rich supply of organic nutrients to benthic invertebrates. The few studies that have documented negative effects on benthic invertebrates as a result of zebra mussel colonization have focused on invertebrate communities living on or around hard substrates. It is not well known how zebra mussels impact infaunal invertebrate species such as burrowing mayflies and chironomids that serve as an important food resource for many fish species. We conducted field-based experiments in two shallow bays located on the eastern shore of Lake Champlain to examine the effects of zebra mussel colonies in soft sediments on the invertebrate community. We predicted that zebra mussel colonies would have a negative effect on infaunal invertebrates while facilitating epifaunal invertebrates. We manipulated zebra mussel colonies *in situ* by either adding or removing zebra mussels in replicate 0.25m^2 plots. Core samples were taken at the beginning and end of a 6–week period to determine changes in invertebrate diversity and abundance. Additional sets of core samples were taken one month after the termination of the experiment in order to provide additional comparisons with the surrounding invertebrate community. The results indicate that zebra mussel colonies on soft sediments affect infaunal invertebrate abundance, diversity, and position within the substrate. The diversity and abundance of infaunal invertebrates declines within sediments after zebra mussel colonization. However, this decline is balanced by an increase in diversity and abundance of infaunal species that were found above the sediment within the zebra mussel colony itself. The majority of species commonly found in soft sediments either increased in abundance or were unaffected after substrate colonization by zebra mussels. Therefore, our data support the notion that most infaunal invertebrates are not adversely affected by zebra mussel colonization of soft sediments. In fact, many infaunal invertebrate species respond to zebra mussels in a positive manner.

NOTES

The Effects of the Hydroid *Cordylophora* sp. and Filamentous Substrate on Larval Settlement in the Zebra Mussel *Dreissena polymorpha*

***Nadine Folino-Rorem**, Emily Thorn, Laura Page and Christopher Flinn*
Biology Department, Wheaton College, Wheaton, IL 60187 USA
T: 630-752-7038 F: 630-752-5996 E: nadine.c.folino-rorem@wheaton.edu

James Stoeckel
Illinois River Biological Station, Illinois Natural History Survey, RR #2, PO Box 590, Havana, IL 62644 USA

The hydroid *Cordylophora* sp. and the zebra mussel *Dreissena polymorpha* are both invasive fouling organisms in the United States that coexist in some freshwater ecosystems. Though a great deal of research focuses on the presence and spread of the zebra mussel, D. *polymorpha*, much less attention has been given to the colonial hydroid *Cordylophora* sp. and the interactions between these two species. The marine literature documents enhanced larval settlement in the presence of filamentous substrate such as hydroids while freshwater literature suggests that hydroids feed on zebra mussel larvae. The purpose of our research was to assess the effects of filamentous hydroid colonies and artificial filaments on zebra mussel settlement.

Field experiments were conducted in the Des Plaines River in Joliet, Illinois where the hydroid and zebra mussels co-occurs and in the Bark River in Delafield, Wisconsin where zebra mussels are abundant but the hydroid is absent. Ten frames containing three PVC treatment plates with live, dead or no hydroids were deployed in the Des Plaines River from late April through August 2002 to assess the effects of the hydroid colonies on mussel settlement. Dead colonies were included to eliminate the potential effect of hydroid predation on mussel larvae. Plates were retrieved and preserved every two weeks and replaced with a new set of treatment plates for the duration of the study. PVC plates with 7.5 cm frayed poly rope attached to the center along with blank control plates were deployed in the Bark River to see if artificial filaments enhanced zebra mussel settlement. Larval samples were taken weekly at both sites to document the supply of zebra mussel larvae of settlement size. In addition to the field experiments, laboratory experiments were conducted to if *Cordylophora* sp. actually consumes zebra mussel larvae. Results indicate that hydroid polyps do not eat smaller larvae and consumption of larger larvae remains rare.

Settlement plates from both sites are currently being analyzed for abundances and sizes of zebra mussel larvae. Preliminary analyses suggest that the artificial filamentous substrate enhanced zebra mussel larvae settlement. The live and dead colonies at the Des Plaines location were dislodged in some instances but seemed to enhance the settlement of other invertebrate fauna. These results will enhance our understanding about how *Cordylophora* sp. colonies and filamentous substrates in general enhance or deter settlement of zebra mussel larvae. Knowing how these two invading species interact will provide information about the impact they have on each other and on endemic aquatic organisms in river ecosystems.

NOTES

What Are the Next Steps Needed to Quantify the Impacts of the Spiny Water Flea, *Bythotrephes*, on Temperate Lakes?

Norman D. Yan
York University, Biology Department,, 4700 Keele Street, Toronto, ON M3J 1P3 Canada
T: 416-736-2100 x22936 F: 416-736-5698 E: nyan@yorku.ca

Hugh J. MacIsaac
Great Lakes Institute for Environmental Research, University of Windsor
29909 Riverside Drive, Windsor, ON N9B 3P4 Canada

Research on impacts of *Bythotrephes* on Canadian Shield lakes is entering its second decade. We will review our progress towards the construction of a quantitative risk assessment for the invasion, considering issues of the rate and extent of spread and types and degrees of impacts in invaded lakes. We show that the Shield has thousands of lakes which can provide *Bythotrephes* with suitable habitat, and that *Bythotrephes* is spreading rapidly among these lakes, probably via the activities of recreational boaters and anglers. We show that the prey communities of *Bythotrephes*, the crustacean zooplankton communities, have changed rapidly, and with some predictability following invasions. Despite this knowledge, we still cannot produce a broadly-based risk assessment, because we do not yet know if invasions are followed by changes in 1) water quality, or phytoplankton composition, 2) fish growth, and yields or 3) changes in sport fish contaminants. Each of these issues warrants examination. Further we cannot provide advice on potential remediation strategies, as we do not know what regulates *Bythotrepehes* abundance, nor do we have a deep understanding of what factors might lead to the extinction of new populations. We need to understand the determinants of the behaviour and life history of *Bythotrephes*, particularly the factors that lead to gametogenesis and resting egg production. As *Bythotrephes* resting eggs appear to be relatively short lived, it may be possible to control new populations if the determinants of resting egg production could be identified.

NOTES

Impacts of Zebra Mussels (*Dreissena polymorpha*) on Foraging Success of Soft-sediment Benthic Predators Vary Depending on Prey Position in the Habitat and Foraging Mode of the Predators

Declan J. McCabe
Biology, St. Michael's College, Box 283, Colchester, VT 05439 USA
T: 802-654-2626 E: dmccabe@smcut.edu

Mark A. Beekey and J. Ellen Marsden
School of Natural Resources, Rubenstein Ecosystem Laboratory, University of Vermont Burlington, VT 05405 USA

Zebra mussels colonize soft sediments, potentially affecting foraging efficiency of benthic predators. Predators dependent on soft sediment-burrowing invertebrates may have reduced foraging success because zebra mussels cover the sediment, or otherwise interfere with prey detection. In contrast, foraging on non-burrowing prey items may be unaffected or enhanced because zebra mussel colonies provide habitat and food for epifaunal invertebrates. To determine the effects of zebra mussel colonization on predation, we established assays using burrowing (*Chironomus* sp.) or non-burrowing (amphipods) invertebrate prey items. Three species with alternate foraging modes, slimy sculpins, brown bullheads, and crayfish, were used as predators. Sculpins detect burrowing prey using substrate vibrations, bullheads use chemosensory/tactile cues, and crayfish search by partially excavating substrate. Zebra mussel density was high (90% cover), low (50% cover), or absent. Treatments were established with and without predators in a full factorial design with predators and zebra mussels as the factors and prey remaining after 48 hours as the response variable. Zebra mussels significantly reduced the number of chironomids removed during the foraging trials of each fish species. Amphipod removal was not influenced by zebra mussel density. In sharp contrast to the results of the experiments using fish predators, zebra mussels did not reduce crayfish foraging success. These results suggest that zebra mussels may significantly reduce the ability of benthic foragers to access burrowing invertebrate prey but not non-burrowing prey. Crayfish, which tend to physically disturb zebra mussel colonies to find prey, may not be similarly impacted.

NOTES

Population Response of Replicate Populations of White Sands Pupfish (*Cyprinodon tularosa*) to Two Exotic Species: the Western Mosquitofish and the Virile Crayfish

David L. Rogowski *and Craig A. Stockwell*
Department of Biological Sciences, North Dakota State University, Fargo, ND 58105 USA
T: 701-231-6561 E: David.Rogowski@ndsu.nodak.edu

The potential impact of introduced species on rare taxa is of particular concern to conservation biologists. Two exotic species, the western mosquitofish (*Gambusia affinis*) and virile crayfish (*Orconectes virilis*) have been introduced throughout the American southwest. These species have been implicated in the decline of a variety of native species, yet their impacts on rare species of pupfish have not been examined. Here we take an experimental approach to evaluate the potential impacts of western mosquitofish and virile crayfish on a New Mexico state listed threatened species, the White Sands pupfish (*Cyprinodon tularosa*) Two of the four habitats occupied by White Sands pupfish are vulnerable to invasion by exotics due to their relatively low salinity. Introduced populations of mosquitofish and virile crayfish occur in habitats of similar salinity and within 19 km of these pupfish populations. Using outdoor mesocosms we investigated the effect of these two exotics on experimental populations of White Sands pupfish. Four treatments with 10 replicates were established each with a population of 16 pupfish. After two weeks, exotics were introduced for three of the treatments, 1 crayfish, 4 crayfish and 5 adult mosquitofish. Pupfish population size was monitored four times over 16 weeks, the duration of the breeding season. A repeated measures MANOVA revealed a significant effect ($p < 0.0046$) of treatments on population size.

Mosquitofish had a significant effect on population size ($p = 0.0169$). The effect of one crayfish was not significant ($p = 0.9082$), however 4 crayfish had a significant effect on population size ($p = 0.0033$). Mean total pupfish population size at the end of the experiment was 27.00 (SD = 11.96) for the controls, and 15.89 (SD = 3.02), 14.10 (SD = 6.1), 27 (SD = 11.95) for treatments with mosquitofish, 4 crayfish, and 1 crayfish respectively. These exotic species pose a serious threat to White Sands pupfish; and management to eradicate or control these species should be pursued by the White Sands Pupfish Conservation Team.

NOTES

Implementation of a Bioenergetics Model for the Round Goby (*Neogobius melanostomus*)

Vicki Lee *and Tim B. Johnson*
Lake Erie Fisheries Station, Ontario Ministry of Natural Resources, 320 Milo Road, Wheatley, ON N0P 2P0
T: 519-825-4686 E: vicki.lee@mnr.gov.on.ca

The round goby (*Neogobius melanostomus*), an invasive species from Eastern Europe, entered the Great Lakes in 1990 through ballast water transfer. They have become an important vector for transfer of energy, nutrients and contaminants from the benthos to the pelagic food web. A bioenergetics model was developed for the round goby using consumption and respiration parameters derived from laboratory experiments. Laboratory results showed both Cmax and oxygen consumption have a strong weight and temperature dependence. Sensitivity analysis was completed to determine the robustness of the model. The model was validated using field studies and observations of the goby population in western Lake Erie to determine biological and demographic information (density, size, diet, energy and contaminant levels). We will present results based on the bioenergetics model quantifying the flow of materials (energy, contaminants) through round gobies in western Lake Erie. We will discuss these results in the context of gobies as a structuring force in recently invaded habitats.

NOTES

Geographical Patterns in Biological Traits of a Sunfish Introduced to Europe – the Pumpkinseed (*Lepomis gibbosus*) and the Implications for Establishment Success

Gordon H. Copp
CEFAS Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk NR33 OHT England
T: 44-1502-527751 F: 44-1502-513865 E: g.h.copp@cefas.co.uk

Michael G. Fox
Environmental and Resource Studies Program and Department of Biology, Trent University, Peterborough, ON K9J 7B8 Canada

Vladimír Kováč
Comenius University, Faculty of Natural Sciences, Department of Ecology, Mlynská dolina B2, SK-842 15 Bratislava, Slovakia

We examined attributes of growth, reproduction and morphology in European populations of pumpkinseed *Lepomis gibbosus*. Weak correlations existed between some morphological characters and latitude, but these may be size related despite accounting for this in the analyses. Mean juvenile growth and age at maturity both correlated with latitude – the values for an English pumpkinseed population being the lowest and highest reported in Europe, respectively. Age-specific growth of the English population was also the lowest in Europe, and mean GSI was also low. Temperature, food resources, cannibalism and predation pressure interact in a complex manner across European pumpkinseed populations, but latitudinal clines in growth and reproduction appear to exist. Late maturity of the English population probably results from relatively low growing-season temperatures, slow growth, poor body condition at age 3 due to limited food resources, and intensive egg predation by high numbers of juveniles, giving a fitness advantage to late-maturing females.

NOTES

Economic Impacts of Invasive Species in Canada: Quantifying the Nonquantified

Hugh J. MacIsaac
Great Lakes Institute for Environmental Research, University of Windsor
29909 Riverside Drive, Windsor, ON N9B 3P4 Canada, Windsor, ON N9B 3P4 Canada
T: 519-253-3000 x 3754 F: 519-971-3616 E: hughm@uwindsor.ca

Despite their profound impacts in Canada, no concerted effort has been made to identify economic impacts of invasive species. We conducted a study to identify impacts of 19 identified invasive species (i.e., those with known economic effects) in aquatic/marine ecosystems, forestry and agriculture in Canada. Even for these species, data were highly fragmented, anecdotal or nonexistent. We developed a model to project potential damage and/or control costs if these species spread widely, based upon the Statistics Canada value of the industry affected by each of these species. We used damage values identified in other studies of invasive species (with 20, 25 and 52% loss estimates). Potential damage is profound: damage to forestry ranges may range between $7.7–20 billion per annum, while that in agriculture and aquatic systems are $5.3–13.9 billion and $299–750 million per annum, respectively. While these values are subject to a large number of assumptions and/or limitations, they illustrate the very high cost of invasive species to key sectors in the Canadian economy. Even though aquatic and marine damage estimates pale in comparison to those in forestry and agriculture, the damage is often geographically restricted with profound cost to specific industries or users. For example, the invasion of clubbed tunicates (*Styela clava*) may cause about a 50% decline in production of aquaculture-grown blue mussels (*Mytilus*), profoundly affecting a growth industry in Prince Edward Island.

Because the frequency of invasions is positively correlated with the GDP (and particularly the level of international trade) of a country, Canada can anticipate further invasions by many species with possible economic impacts. The Canadian federal government is presently ill-prepared to address problems caused by invasive species because it lacks a coordinated, funded, pro-active strategy. The recent invasion of the Essex County, Ontario, region by emerald ash borer (beetles) portends the next 'Dutch Elm Disease'-calibre invasion of Canadian forests, and with it its massive attendant economic impact; this invasion highlights the federal government's impotence and complacency with regard to protecting Canadian ecosystems from invasive species.

NOTES

Environmental and Economic Costs of Invasive Alien Species in Canada

Renata Claudi
RNT Consulting Inc., R.R.2 Picton, ON K0K 2T0 Canada
T: 613-476-7994 F: 613-476-7994 E: rnt@idirect.com

Understanding the magnitude of the environmental and economic costs of invasive alien species is essential for establishing the scope of the issue. There are only two aggregate cost estimates of the impact of invasive alien species at the national level, both for the United States (OTA 1993; Pimentel et al. 2000).

This study, sponsored by Canadian Information System for the Environment (CISE), attempted to summarize available economic data on the costs of invasives in Canada. As the timeframe for the study was very limited, a sub-sample of 50 specific species known to have major economic and environmental impacts was used.

This presentation will deal with the economic costs found, the pitfalls encountered, the gaps that exist in our knowledge and recommendations for a path forward.

NOTES

The Champlain Canal: A Conduit for Exotic Species

J. Ellen Marsden
University of Vermont, Aiken Center, Burlington, VT 05405 USA
T: 802-656-0684 F: 802-656-8683 E: emarsden@nature.snr.uvm.edu

Michael Hauser
Vermont Department of Environmental Conservation, Lake Champlain Basin Program
103 South Main Street, Waterbury VT 05671-0408 USA

Mark Malchoff
Lake Chaplain Sea Grant, 101 Hudson Hall, Plattsburgh State University, 101 Broad Street, Plattsburgh, NY 12901 USA

Lake Champlain drains northward into the St. Lawrence River, and is linked to the Great Lakes, Mohawk, and Hudson Rivers to the south by the Champlain Canal. Despite these linkages, the lake has received relatively few exotic species compared with the Great Lakes; this may in part be due to the absence of modern commercial traffic in the lake. Over 45 exotic species are present in Lake Champlain, including fishes, crayfish, plants, smaller crustaceans, and mollusks. The route of invasion has so far only been determined for 25 species, and of these, approximately 60% appear to have entered through either the Champlain Canal to the south (12), or the Chambly Canal to the north (3). Lake Champlain has also served as a conduit for invasions between the ecosystems to which it is linked. As in the Great Lakes, the rate of invasions is apparently increasing; four new fish species, five molluscs, a crustacean and a fish pathogen have appeared in the lake drainage within the last ten years. Of continuing concern is the potential for future invasions to occur via the canals. The Great Lakes already have 160 exotic species, and more are arriving almost every year from Europe and other parts of the world in shipping. Species that are already within potential invasion distance of the Champlain Canal include the round goby, quagga mussel, Asian clam, spiny water flea, and fish-hook flea. We are evaluating potential methods to reduce to exotic species passage through the Champlain Canal, including electrical, physical, chemical, and biological barriers. A cost:benefit analysis is being developed with input from technical experts and from public and private stakeholders in the basin. Ultimately, recommendations for potential exotic species barrier options will be made available to policy-makers.

NOTES

Economic Impacts of Hydrilla Infestations to Angling in Lakes Moultrie and Murray, South Carolina

Jim E. Henderson and ***James P. Kirk***
US Army Engineer Research and Development Center, Environmental Lab
3909 Halls Ferry Road, Vicksburg, MS 39180-6199 USA
T: 601-634-3060 F: 601-634-2398 E: Kirkj@wes.army.mil

Scott D. Lamprecht
South Carolina Department of Natural Resources, Dennis Wildlife Center, Bonneau, SC 29431 USA

W. Eugene Hayes
South Carolina Department of Natural Resources, 108 Highland Drive, Greenwood, SC 29646 USA

Angler creel surveys and economic impact models were used to evaluate the potential expansion of hydrilla (*Hydrilla verticillata*) in Lakes Murray and Moultrie, South Carolina. In both systems, hydrilla coverage had been either eliminated or substantially reduced causing concerns among angler groups. In Lake Murray, control measures included herbicides and draw downs that lowered coverage to about 800 ha while triploid grass carp (*Ctenopharyngodon idella*) were used to reduce the infestation in Lake Moultrie from thousands if hectares to less than 20 ha. Anglers were asked to describe their angling efforts at current level of aquatic plant coverage, at an intermediate level of coverage, and at former peak levels of coverage. Based upon their experiences with aquatic vegetation, all categories of anglers preferred increased aquatic vegetation, including hydrilla. Increasing plant coverage from current levels would increase angling effort by 11% to 14% and increase economic activity in selected economic sectors, such as lodging, by 18% to 63%. Expenditure data and economic impact models are an improved approach to measure economic contributions of angling. Other groups that may prefer lower plant coverage, such as pleasure boaters, water skiers, hunters, and homeowners along the lakes, should be studied using similar methods. Taken together, this approach incorporates public preferences, perceptions, economic benefits in the local economy, and provides justification for aquatic plant management.

NOTES

Canada's National Code for Introduction and Tranfers of Aquatic Organisms

Iola Price
Oceanography and Aquaculture Science Directorate, Fisheries and Oceans Canada
200 Kent Street, Ottawa, ON, K1A 0E6 Canada
T: 613-991-6850 F: 613-993-7665 E: pricei@dfo-mpo.gc.ca

In 1995, the Fisheries and Oceans Canada began work on a Code on Introductions and Transfers of Aquatic Organisms (the Code) to govern the deliberate movement of live aquatic organisms, between provinces and territories or within them, in an effort to minimize undesirable impacts from intentional introductions and transfers. Its intent was (and still is) to protect aquatic ecosystems while encouraging the responsible use of aquatic resources for the benefit of Canadians and be consistent with Canada's obligations as a Party to the 1992 Convention on Biological Diversity.

When constituted in 1999, the Canadian Council of Fisheries and Aquaculture Ministers (CCFAM) established the Task Group on Introductions and Transfers. A major part of the Task Group's mandate was to finalize the Code, while taking into account the concerns of stakeholders across Canada. The CCFAM adopted the Code in September 2001 and, at the same time, established an 18-month implementation and review period. The Code is posted on the DFO website at:

http://www.dfo-mpo.gc.ca/science/aquaculture/code/prelim_e.htm.

The Code applies to the introduction of a species exotic to the waters of a province or territory, as well as to the transfer of indigenous or naturalized exotic species from other countries or between provinces or territories. The Code also covers deliberate range extensions of a species within a province or territory and transfers of indigenous or naturalized exotic species within a province or territory if there is no other review process. Implementation of the Code is the responsibility of provincial and territorial governments in those jurisdictions where they are responsible for the fishery. DFO will continue to provide advice and support, and act as the liaison between Canada and the US and France regarding international fisheries issues.

This presentation will describe the Code and CCFAM Task Group activities over the period 1999-2003 and provide information on the 18-month implementation and review. An updated Code, based on Task Group and Stakeholder input will be proposed to the CCFAM in September.

NOTES

Policy, Legislation and Monitoring

The Millennium Challenge: The US Environmental Protection Agency's Response to Invasive Species

Henry Lee II
US EPA Coastal Ecology Branch, 2111 SE Marine Science Drive, Newport, OR 97365 USA
T: 541-867-5001 F: 541-867-4049 E: lee.henry@epa.gov

Russell Kreis
US EPA, Office of Research and Development/NHEERL, 9311 Groh Road, Grosse Ile, MI 48138 USA

Marc Tuchman
US EPA, Great Lakes National Program Office, 77 West Jackson Boulevard, Chicago, IL 60604 USA

Michael Slimak
US EPA, Office of Research and Development/NCEA, 401 M Street S.W., Washington, DC 20460 USA

Ronald Landy
US EPA, Region 3

Marilyn Katz and John Heisler
US EPA, Office of Water/OWOW

Russell Jones
US EPA, Office of Prevention, Pesticides, and Toxic Substances/OP

William Holland
US EPA, Gulf of Mexico Program Office, Bldg. 1103, Room 202, Stennis Space Center, MS 39529 USA

Peter Christich
US EPA, Office of International Affairs

Joan Cabreza
US EPA, Region 10

The US Environmental Protection Agency (EPA) is responding to the scientific and regulatory challenges of invasive species in a variety of ways. One response has been to use existing programs and regulations, as appropriate, to address invasive species. A recent example is the granting of an emergency exemption under FIFRA, the act that authorizes the registration of pesticides, to permit the application of caffeine to control two species of exotic frogs in Hawaii. Another area were the EPA is playing an important role is in the US–Canada Boundary Waters Treaty, which requires prevention and control of aquatic invasive species to avoid and minimize as much as possible harm to the biological and aquatic integrity of inland boundary waters along the 5500-mile border. The EPA also has an important role in ballast water management, including participation in the setting of international ballast water standards through the International Maritime Organization (IMO) and the evaluation of ballast water treatment technologies. Another type of response has been to incorporate invasive species into EPA programs not originally designed to address exotic species. With the growing awareness of their potential ecological impacts, half of the 28 National Estuary Programs (NEPs) have recently identified invasive species as a moderate or major threat. Invasive species have also been identified as a serious risk in the Gulf of Mexico and Great Lakes Programs. EMAP, EPA's large-scale monitoring program for surface waters and estuaries, has recently incorporated invasive species as a measure of ecological condition along with pollutants. Other efforts are being undertaken to design ecosystem restoration methods to minimize the intentional use of non-native species and the unintentional spread of invasive species. Yet another type of response has been to conduct the research needed to predict ecosystem vulnerability and the ecological risks associated with invasive species. Such research is being conducted within the EPA and funded through EPA's grant program. An example of joint EPA-academic research is an effort to predict a habitat's vulnerability to invasion by specific invaders using the "Genetic Algorithm for Rule Set Prediction" (GARP) model. An example of an EPA research effort is the evaluation of patterns of invasion in West coast

estuaries as they relate to exposure to ballast water discharges and oyster culture. Even with these efforts, many challenges remain, including: 1) developing techniques/management practices to minimize the introductions of new aquatic invaders; 2) developing rapid assessment approaches to identify and control new aquatic invaders; and 3) developing the understanding and tools to predict the impacts of invasive species on key ecosystem functions (e.g., sedimentation) especially as they relate to ecosystem condition, water quality, and pollutant fate and effects.

NOTES

Analysis of Canadian and American Legislation for Controlling Exotic Species in the Great Lakes

Charlotte Vásárhelyi *and Vernon G. Thomas*
Department of Zoology, College of Biological Science, University of Guelph, Guelph, ON N1G 2W1 Canada
E: vthomas@uoguelph.ca

We analyzed the legislation of the Great Lakes jurisdictions dealing with control of exotic species introduced through ballast water, canals, and recreational boating to determine whether the USA and Canada have the capacity to manage nuisance exotic species effectively. Despite the deleterious ecological effects attributed to exotic aquatic species, there is a lack of complementary legislation between Canada and the USA to remedy this problem. Current legislation is fragmented at the bilateral, national, and the state/provincial level.

American legislative initiatives are far ahead of Canada's, especially for regulating ballast water in oceanic shipping. Canada lacks strong federal and provincial legislation to regulate ballast water in shipping and to prevent the secondary spread of exotic aquatic species through watersheds.

Legislation to regulate ballast water is developing quickly among the US federal government and the Great lakes states. However, legislation affecting the spread of exotic nuisance species via canals and recreational boaters is needed to complement ballast water laws and to give agencies a broader mandate for management.

Amendment of the Boundary Waters Treaty Act, the Fisheries Act, and the Canada Water Act could give the Canadian federal government authority to regulate ballast water in vessels entering the St. Lawrence and to begin the rehabilitation of aquatic habitats impaired by nuisance exotic species.

Preventing further species introduction and spread through the Great Lakes basin requires restricting certain shipping and boating practices. That can be achieved only by the enactment of complementary laws among all the American and Canadian jurisdictions.

NOTES

A Case Study of Canada's Response to Aquatic Invasive Species Introductions

Francine MacDonald
Ontario Federation of Anglers and Hunters, PO Box 2800, Peterborough, ON K9J 8L5 Canada
T: 705-748-6324 F: 705-748-9577 E: francinem@ofah.org

In July 1999, the invasive aquarium plant *Cabomba caroliniana* was reported in Kasshabog Lake, northeast of Peterborough, ON. Native to south temperate and subtropical regions of North and South America, *C. caroliniana* has previously invaded lakes in New England with serious effects on lake ecosystems and recreational water uses. Based on concerns that similar effects could be realized in Ontario, several stakeholder groups have attempted to initiate action to deal with this introduction to 1) assess its potential impacts to aquatic ecosystems and its potential to spread within Ontario waters; and 2) prevent overland spread from recreational watercraft and as well prevent additional releases by aquarium hobbyists. These attempts have identified several major weaknesses in Canada's capacity to respond to aquatic nuisance species introductions and their spread. These include the need for a coordinated governmental approach to assess the risks of alien introductions to aquatic ecosystems, and the lack of any national response plan to deal with these introductions while eradication measures are still feasible.

This paper examines some of the failures in current policy to provide adequate support for assessing the impacts of aquatic invaders, re-evaluating the importation of invasive species and initiation of prevention and control strategies.

NOTES

Stopping the Ballast Water Stowaways – The Global Ballast Water Management Programme Initiative

Arga Chandrashekar Anil
National Institute of Oceanography, Dona Paula, Goa, 403 004 India
T: 91-832-2456700 x 4404 F: 91-832-2456702 E: acanil@darya.nio.org

Hassan Taymourtash
Marine Protection Dept., Ports & Shipping Organization, Ministry of Road Transportation, No. 71 Enghelab Ave, Teheran 159966 1467, Islamic Republic of Iran

Marine species are being carried around the world in ships ballast water. When discharged into new environments, they may become invasive and severely disrupt the native ecology, impact economic activities such as fisheries and cause disease and even death in humans. Invasive marine species are one of the four greatest threats to the world's oceans and the other three are land based sources of marine pollution, over exploitation of living marine resources and physical alteration and destruction of coastal and marine habitat. A problem may arise when ballast water taken by a ship contains unwanted marine organisms. Once established, it is virtually impossible to control an invasive marine species. Impacts are usually irreversible. International Maritime Organization (IMO) has joined forces with Global Environment Facility (GEF) and the United Nations Development Programme (UNDP) to assist countries to reduce the transfer of invasive marine species in ballast water. The Global Ballast Water Management Programme (GloBallast) is working through six initial demonstration sites (Brazil, China, India, Ir. Iran, South Africa and Ukraine) to prepare for the new International regulatory regime. Activities carried out under GloBallast include: education and awareness, ballast water risk assessments, port baseline surveys, ballast water sampling, training port and shipping personnel in ballast water management practices, assistance with laws and regulations and self financing mechanisms. An overview of this initiative is presented.

NOTES

Preventing Aquatic Nonindigenous Species in the United States Through Regulation, Research, and Management

CDR Patrick Gerrity
Marine Safety Office Detroit, US Coast Guard, 110 Mt. Elliott Avenue, Detroit, MI 48207- 4380 USA
T: 313-568-9580 F: 313-568-9581 E:

Aquatic nuisance species (ANS) are increasingly viewed as a global environmental problem with large and long-lasting ecological and economic impacts. Introduced into habitats where they are not native, ANS can degrade ecosystems, resulting in billions of dollars of direct and indirect costs annually, as well as adverse effects on human health and lifestyles.

The Coast Guard's ANS Program focuses on ballast water management (BWM) options that can prevent the introduction of ANS via ballast water. Two pieces of Federal legislation, the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 and the National Invasive Species Act (NISA) of 1996, require the Coast Guard to promulgate regulations and guidelines that establish BWM practices to meet this objective.

Four regulatory projects are in progress and listed below.

- Establishing penalties for vessels failing to report BWM practices.
- Require all vessels to conduct active BWM.
- Allow for shipboard testing and evaluation of treatment technologies.
- Establish a quantitative ballast water discharge performance standard.

A key hurdle to developing accepted ballast water treatment (BWT) technologies is the absence of a standard by which proposed technologies can be evaluated. The Coast Guard is leading a coordinated effort to develop this standard.

The Coast Guard has established a formal engineering test program (Environmental Technology Verification Program) with the Environmental Protection Agency to accelerate development and commercialization of BWT technologies.

The Coast Guard leads US participation in negotiations at the International Maritime Organization to establish a legally binding international instrument to regulate ballast water discharges.

We are seeing the early stages of these efforts and are optimistic that they will grow and bear fruit. We use the phrase "scientifically supportable, biologically meaningful, and verifiable" to characterize what we want in our domestic BWM program.

NOTES

The Development of the International Convention for the Control and Management of Ships' Ballast Water and Sediments

Tom Morris
Manager Environmental Protection, Marine Safety, Transport Canada, AMSEE, 330 Sparks St., Ottawa, Ont. Canada K1A 0N8
T: 613-991-3170 F: 613-993-8196 E: morrist@tc.gc.ca

The threat of introductions of harmful aquatic organisms and pathogens from the discharge of ship's ballast is an international issue that is appropriately being addressed by the International Maritime Organization (IMO), the United Nations specialized agency that deals exclusively with marine matters. The IMO's Marine Environment Protection Committee (MEPC) has identified addressing the ballast water issue as its number one environmental priority.

The IMO first developed guidelines on the management and control of ballast water in 1991 and, since 1994, has been working on the drafting of mandatory regulations. The process was interrupted in the late 1990s when it was recognized that an update to the guidelines was necessary.

In attempting to reach consensus on the contents of the regulations, many issues have been debated, such as a global vs. regional approach, the continued acceptance of ballast water exchange and requirements for new ships vs. existing ships, but the greatest challenge has been to develop treatment and discharge standards. When the Working Group developing the regulations met in March 2002, they considered 14 possible ballast water treatment standards, which they have since reduced to just one performance standard, but the parameters for the standard remain undecided.

As currently drafted the regulations would require ships to carry an approved Ballast Water Management Plan, to keep a Ballast Water Management Book, and to manage sediment and ballast. New ships would be required to discharge no detectable quantities of viable organisms above a certain size (proposed as 50 microns) and to discharge no other organisms above a certain concentration (to be determined). Existing ships conducting ballast exchange would have to do so with an efficiency of 95% volumetric exchange, but only those ships constructed before the entry into force of the Convention would be considered as conducting an equivalent exchange by using three times flow through. Issues such as the parameters for the performance standard, the definition of a new ship, the decision of whether or not ballast water exchange will be phased out for existing ships, whether special requirements are required in certain areas and whether special areas should be established are still significant items being debated.

The MEPC will further discuss the proposed ballast water convention when it meets again in July 2003. If issues can be resolved, it is expected that the Convention would be adopted at a Conference of Parties in early 2004. The Convention would then come into force when a sufficient number of countries ratify it after implementing its provisions in their national legislation.

NOTES

Perceptions of Ballast Over Hull Fouling as Primary Invader Vectors

Chad Hewitt
Chief Technical Officer, Ministry of Fisheries, P.O. Box 1020, 101-103 The Terrace, Wellington, 6001, New Zealand
T: 64-4-470-2582 F: 64-4-470-2686 E: Chad.Hewitt@fish.govt.nz

This abstract was not available at the time of printing.

NOTES

Ballast Water Management Practices of Foreign Flag Vessels

Anjuna Langevin
Shipping Federation of Canada, 300 St. Sacrement St., Suite 326, Montreal, QC H2Y 1X4 Canada
T: 514-849-2325 F: 514-849-8774 E: alangevin@shipfed.ca

The Shipping Federation of Canada is an association of ship owners, commercial operators and agents who represent 95% of Canadian-owned oceanic traffic moving to and from ports on the east coast, the St. Lawrence and the Great Lakes. The Federation has been an active player in the implementation of ballast water management regulations for the Great Lakes, and is keenly interested in the development of a regionally coordinated approach to ballast water management that is based on internationally accepted standards and practices. In 2000, the Federation developed a "Code of Best Practices for Ballast Water Management," which is a voluntary program used by oceans ships as a means of minimizing the risk of introducing non-indigenous aquatic organisms and pathogens into the Great Lakes. The code enumerates a variety of measures that ships agree to undertake in this respect, including the cleaning of tanks, commitments with regard to areas and periods for ballast water intake, and agreement to conduct ballast water management at every practical opportunity.

Oceanic shipping is an international activity by its very nature, with ships sailing many different routes throughout the world. The masters and crews of those vessels are subject to an increasing number of standards, procedures and regulations. As a result, it is important to ensure that such rules and regulations are as simple and user friendly as possible.

Foreign-going vessels rarely have to conduct full ballast exchange along the east coast (which would take 24 to 30 hours, or some 350 nautical miles, to complete). They more frequently exchange ballast from two or three tanks (which takes 8 to 9 hours). However, coastal vessels coming from ports along the east coast or the Atlantic provinces usually find it impossible to conduct a full exchange outside the Economic Exclusive Zone (more than 200 nm from shore) due to their trading limits. Thus, such vessels have, until now, been exempted from requirements to comply with Canadian and US ballast water guidelines.

We believe that the most viable means of addressing cases in which vessels are unable to exchange ballast water at sea (due to safety considerations or coastal trade limitations) is to define a clear alternative ballast water management option. Effective development and use of such a zone or procedure would, however, require bi-national coordination.

It is extremely important that any effort to develop new measures governing ballast water management be consistent with the guidelines and regulations that are either already in place or under development at the international and national level. Legislators should also bear in mind that frequently changing limits and reporting procedures over a short period of time would lead to confusion and a reduction in compliance. A common approach from the Atlantic provinces and the States on the East Coast is absolutely essential.

Ballast water treatment systems are probably the more promising tool for effective ballast water management. The Shipping Federation supports the development of efficient treatment options and some of its members have installed trial systems on their vessels. However, at this stage, none of the systems that are available on the market have proven to be sufficiently effective to be installed on a large scale. In addition, treatment systems represent major financial investments that ship owners are not likely to undertake until an international or national standard has been developed. It is also important to remember that the installation of treatment systems on board fleets could take several years given the extensive dry-docking that might be required. Thus, given the highly competitive environment in which shipping takes place, any effort to impose a treatment requirement on vessels calling at a particular state or region would result in a diversion of cargo to other ports and threaten the economy of the region as a whole.

The Great Lakes NOBOB Project: 38 Ships and 82 Tanks Later

Tom Johengen *and Hong Ying*
CILER/University of Michigan, 2200 Bonisteel Blvd., Ann Arbor, MI 48109 USA
T: 764-2426 F 734-647-0768 E: johengen@umich.edu

David F. Reid and Gary Fahnenstiel
NOAA/GLERL, 2205 Commonwealth Blvd.Ann Arbor, MI 48105-1593 USA

Philip T. Jenkins
Philip T. Jenkins and Associates Ltd., 1 Forest Hill Crescent, Fonthill, ON L0S 1E1 Canada

Fred C. Dobbs and Martina A. Doblin
Old Dominion University, 4600 Elkhorn Avenue, Norfolk, VA 23529 USA

Hugh J. MacIsaac, Colin Van Overdijk and Sarah Bandoni
Great Lakes Institute for Environmental Research, University of Windsor
29909 Riverside Drive, Windsor, ON N9B 3P4 Canada

The majority of vessels arriving from overseas to the Great Lakes enter as NOBOBs (no-ballast-on-board). A major goal of the Great Lakes NOBOB Project is to assess whether these vessels are a potential vector for nonindigenous aquatic species introductions to the Great Lakes. Task 1 of the project is to characterize the amount, and biological and chemical content of sediment and water residuals within NOBOB ballast tanks. Over a two-year period, 82 ballast tanks were entered and sampled on 38 different vessels. Salinities of residual water ranged from 0 to 36 ppt, with approximately 50% in the fresh to brackish water range. In residual water samples we found: bacterial levels typical of environmental samples, occasional presence of pathogenic protozoa, Pfiesteria, and vibrio cholerae; live phytoplankton cells in all samples, including nonindigenous species, that exhibited various growth response during experimental grow-outs; and over 45 species of live zooplankton including nonindigenous species. In residual sediments we found: viable phytoplankton cysts in all samples, including nonindigenous species of diatoms and marine dinoflagellates (some HAB species); and zooplankton resting eggs in all samples, including nonindigenous species, at densities ranging from 100–10 000 eggs/m^2 with an average viability of 36% under experimental hatching studies.

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Ballast Management and the Control of Sediment Accumulation in Water Ballast Tanks

Capt. Philip T. Jenkins
Philip T Jenkins & Associates Ltd., 1 Forest Hill Crescent, Fonthill, ON L0S 1E1 Canada
T: 905-892-0581 F: 905-892-0581 E: seafarer1@sprint.ca

Ballast water management, including the management of residuals, has been identified internationally as the only existing defense against the proliferation of aquatic nuisance species through the vector of international shipping, and is likely to remain so in the near term. In the context of protection of the Great Lakes, ballast management was initially viewed solely as open ocean exchange for ships proceeding on the transoceanic voyage in ballast. However the vast majority of ships entering the Great Lakes from overseas do so with cargo on board and with only unpumpable ballast residual in their tanks, which will eventually commingle with water ballast taken in and subsequently discharged within the Great Lakes basin.

For these ships, the other elements of ballast management become critical, as they can be ballasting at both ends of the transoceanic voyage in fresh or brackish water without the prophylactic effect of saline shock that open ocean exchange provides. Unpumpable ballast, the residual that cannot be stripped from the tanks, is as much a factor of commercial shipping as ballast water itself, as there are few ships, particularly in the dry bulk trades that can completely evacuate their ballast during the course of the deballasting/cargo loading cycle. Sediment intake during ballasting, particularly at berths in rivers and estuaries, may be unavoidable, and once precipitated can form a major component of that residual if not addressed promptly and regularly.

Significant efforts are being made by the industry for both commercial and environmental reasons to manage residuals. This presentation, based on field observations of the deep sea Great Lakes trade over a six year period in studies sponsored by Fisheries and Oceans, Canada, Sea Grant and the Great Lakes Protection Fund as part of their overall assessment of NOBOB ships, examines the management options available to the ship operator for limiting or eliminating these residuals, the technical and operational limitations that they currently deal with, and the overall application and effectiveness of sound management practice in the trade.

NOTES

Do Resting Eggs in Ballast Tanks Pose an Invasion Risk?

Sarah A. Bailey, *Ian C. Duggan, Colin D.A. van Overdijk and Hugh J. MacIsaac*
Great Lakes Institute for Environmental Research, University of Windsor, 29909 Riverside Drive, Windsor, ON N9B 3P4 Canada
T: 519-253-4232 F: 519-971-3609 E: sarahbailey@canada.com

Ship-mediated biological invasions continue to be recorded within the Great Lakes, despite the implementation of ballast water exchange regulations in 1993. We explore whether vessels declaring no ballast on board (NOBOB) status, being currently exempt from regulations, may be a vector for introduction of nonindigenous species (NIS) to the Great Lakes. These vessels potentially pose an invasion risk owing to the presence of viable invertebrate resting eggs contained in residual sediment. NOBOB ships that ballast and deballast Great Lakes water while in transit may deposit invertebrates or their resting eggs. To determine the possibility that NOBOB sediments act as a vector for NIS we investigated the density, diversity and viability of invertebrate resting eggs within residual sediments of 69 tanks on 39 vessels over two years. The density and viability of resting eggs varied widely, from 0.3 to 91.3 eggs/g sediment and 0 to 92%, respectively. Viability of resting eggs was explored under various day length and salinity conditions. Here, we report preliminary findings from hatching experiments, providing the first evidence that residual sediments can carry viable invertebrate resting eggs. Thirty-three species have been identified to date, seven of which are not currently established in the Great Lakes. In addition, we will present preliminary findings on the effect of saltwater exposure on viability of freshwater species' resting eggs.

NOTES

Ballast Tank Biofilms as "Seed Banks": Physicochemical and Microbiological Characterization

Anne E. Meyer, *Robert L. Forsberg and Robert E. Baier*
Industry/University Center for Biosurfaces, University at Buffalo, 110 Parker Hall, Buffalo, NY 14214-3007 USA
T: 716-829-3560 F: 716-835-4872 E: aemeyer@acsu.buffalo.edu

Lisa A. Drake, Laura K. Scott, Fred C. Dobbs, Martina A. Doblin
Old Dominion University, Department of Ocean, Earth & Atmospheric Sciences, 4600 Elkhorn Avenue, Norfolk, VA 23529 USA

Michael Koch and William P. Johnson
University of Utah, 135 South 1460 East, Salt Lake City, UT 84112 USA

Lessons repeatedly learned from the past underscore the need for control of ship-surface biofouling and source ballast water. The probability of successful establishment of self-sustaining populations of exotic species is expected to increase with greater volumes of ballast water and reduced ship transit times. In addition to potential environmental and public health impacts caused by invasive species, modern aquaculture development in coastal zones is at risk of disease transfer from ballast water. More recently, the potential for ballast-tank biofilms to act as "vertical seed banks" during and after multiple ballast exchanges has become a specific concern. The overall goal of this multi-university collaboration is to assess the potential for ballast-tank biofilms to globally transport microorganisms and pathogens. Previous field experiments during transoceanic voyages demonstrated that biofilms form on multiple types of artificial surfaces deployed in ballast-water holds. When the substrata and associated biofilms were removed from the hold and submerged in sterile artificial seawater, they readily seeded secondary biofilms. In addition to bacterial populations, the primary biofilms contained a significant contingent of protista, which themselves may carry bacteria and viruses harmful to humans and other species. Continuing field experiments include deployment of controlled-surface sampling units in ships' ballast tanks, aseptic collection of biofilms from the walls of recently deballasted tanks, and laboratory experiments with a 260-gallon (1 m^3) model ballast tank supplied with sand-filtered Lake Erie water. Analyses of field biofilm samples have revealed the presence of potential pathogens, including Pseudomonas putrefaciens, Vibrio alginolyticus, and Vibrio cholerae. The Vibrio cholerae detected were not representatives of human-cholera serogroups. Dinoflagellate cysts recovered from field biofilm samples later germinated to swimming cells. Contrary to our expectation of biopolymer-rich films, biofilms collected from the walls of deballasted tanks were richer in silicates and silica, as indicated by infrared spectroscopy and supported by SEM/EDXray observations of sediments. An apparent lack of substantivity (lack of adhesion to the substratum) indicated that portions of ballast biofilms can be easily stripped from tank walls under modest shear. Although not surrounded by the usual slime components of biofilms from nutrient-rich systems, as detected by infrared spectroscopy, a thriving microbial community was revealed by light microscopic and immunofluorescence analyses of ballast biofilms. When replicates of these test plates were subjected to controlled shear conditions (stagnation point flow cell apparatus), much of the micro-particulate and microbial load was removed. Subsequent immunofluorescence analysis of the shear-challenged samples, however, showed that populations of target organisms were still present on the surface. These, more strongly retained, organisms can survive in the biofilm to produce new generations of cells for later release into the ballast water. In the model ballast tank containing Lake Erie water seeded with ballast-tank sediment, biofilms formed readily on all test surfaces. Preliminary light microscopic analyses of these biofilms revealed bacteria and protista. Species identifications are underway.

The research described here is partially supported by a National Sea Grant College Program award, via the Virginia Graduate Marine Science Consortium, to Old Dominion University.

NOTES

Effects of Temperature on Chronic Hypoxia Tolerance in the Nonindigenous Brown Mussel, *Perna perna* (Bivalvia: Mytilidae) from the Texas Gulf of Mexico

David W. Hicks
Center for Coastal Studies, Texas A&M University-CC,, 6300 Ocean Drive, Corpus Christi, TX 78412 USA
T: 361-825-3230 F: 361-825-2770 E: dhicks@falcon.tamucc.edu

Robert F. McMahon
Department of Biology, The University of Texas at Arlington, Box 19498, Arlington, TX 76019 USA

The effects of temperature (15°, 20°, and 25°C), O_2 concentration (Po_2 = 0, 7.9, 15.9, 31.8, and 47.5 Torr), and individual size (12-79 mm) on survivorship of specimens of the nonindigenous brown mussel, *Perna perna* from the Texas Gulf of Mexico Coast were investigated in order to assess its potential distribution in North American coastal waters. The hypoxia tolerance of *P. perna* was temperature dependent, survivorship being significantly extended at low temperatures under all tested lethal O2 concentrations. Survivorship in 15°C anoxic seawater was significantly greater than in much higher O_2 concentrations (e.g., 31.8 Torr) at 25°C. In contrast, hypoxia tolerance was less affected by O_2 concentration. At 25°C, survivorship was not significantly different over a Po_2 range 0–15.9 Torr and significantly increased only at 31.8 and 47.5 Torr. Survivorship was also size dependent. Median survival times at varying percentiles of individual shell length (SL) distribution increased with increasing SL in both anoxia and 7.9 Torr, but at 15.9, 31.8, and 47.5 Torr, this trend was reversed, with smaller individuals surviving longer than larger individuals. The hypoxia tolerance of *P. perna* was similar to other intertidal bivalves and to estuarine infaunal bivalve species that encounter environmental hypoxia more often. Thus, hypoxia tolerance does not appear to prevent open-water intertidal species, such as *P. perna*, from invading estuarine environments. Other parameters, particularly temperature tolerance, appear more important. Ephemeral presence of *P. perna* populations in some Texas estuarine habitats suggests that conditions can be temporarily conducive to settlement and growth. However, episodic hypoxia and high summer water temperatures may make Gulf of Mexico estuarine habitats inhospitable to long-term *P. perna* colonization.

NOTES

Temperature Acclimation of Acute Upper Thermal Limits in Zebra Mussels (*Dreissena polymorpha*) from the Arkansas River, Oklahoma, Relative to that of Mussels from the Niagara River, New York

Robert F. McMahon *and David K. Britton*
Department of Biology, The University of Texas at Arlington, Box 19498, Arlington, TX 76019 USA
T: 817-272-2412 F: 817-272-2855 E: r.mcmahon@uta.edu

Specimens of *Dreissena polymorpha* where collected at an ambient water temperature of 16.8°C on 12 October 2000 from a dewatered intake structure of US Corps of Engineers, Robert S. Kerr Hydroelectric Power Station on navigation mile 336.2 of the Arkansas River, approximately eight miles south of Sallisaw, Leflore County, Oklahoma. Collected individuals were immediately returned emersed on damp paper toweling in an insulated container to The University of Texas at Arlington and held in dechlorinated tap water at 15°C for 39 Days. Mussels were then acclimated to 5°, 10°, 15°, 20°, 25° and 30°C for a period of 28–30 days after which the acute upper thermal limits of 5 subsamples of each acclimation group were determined. Acute upper thermal limits were determined for a total of 77–102 individuals in the 5–25°C acclimation groups. Total sample size was 44 for 30°C acclimated individuals due to extensive sample mortality during acclimation. Acclimation group subsample acute upper thermal limits were determined by exposure to temperature increasing at 0.1°C min^{-1} from the acclimation temperature until 100% sample mortality was achieved. Individuals were considered dead if their shell valves widely gaped and did not close on stimulation of the posterior mantle margin with the tip of a dissecting needle. The modal upper acute lethal temperature for the 5°C acclimated group was 39°C. It was 40°C for individuals acclimated to 10°, 15° and 20°C and 41°C for individuals acclimated to 25° and 30°C, suggesting that temperature acclimation over 5° to 30°C resulted in a roughly 2°C increase in acute upper thermal limit. Extensive mortality during the 28–30 day 30°C acclimation period indicated that 30°C was the incipient upper thermal limit of Arkansas River mussels. The modal acute upper temperature limits for Arkansas River mussels acclimated over 5°-30°C of 39°–41°C were somewhat greater than the range of acute LT_{50} values of 35°–39°C determined using the same methodology and acclimation temperatures for specimens of *D. polymorpha* from Black Rock Navigation Lock on the Niagara River, Buffalo, New York. Thus, zebra mussels may have evolved an elevated acute thermal tolerance under the selective pressure of elevated summer ambient water temperatures in the Arkansas River which, at a maximum of 27.8°C, approach this species 30°C incipient upper thermal limit. Such increased acute upper limits may allow Arkansas River zebra mussels to better tolerate short-term, diurnal exposure to elevated day-time water temperatures during summer months. However, both Arkansas River and Niagara River mussels had a similar chronic, upper incipient temperature limit of 30°C, suggesting that *D. polymorpha* is unlikely to become established in North American inland waters in which summer water temperature exceeds 30°C for extended periods.

NOTES

A Comparison of Metabolic Enzyme Activities and Proximate Composition of Zebra and Quagga Mussels

Ann Stoeckmann, *Renée Bishop, Jana Finkenstadt, Liana Vitelli, Steve Pipitone and Sean Wolfe*
Penn State University – Worthington Scranton, 120 Ridge View Drive, Dunmore, PA 18512 USA
T: 570-963-2529 F: 570-963-2535 E: ams18@psu.edu

The displacement of zebra mussels by quagga mussels throughout much of their range implies that quagga mussels possess some characteristic that gives them the advantage in their competition with zebra mussels. Because they are so similar, the displacement may be due to differences in their physiology and how they allocate energy. Other studies have determined that metabolism is the major energetic expense for zebra mussels and that quagga mussels have lower metabolism, indicating lower energy costs. Quagga mussels are also larger than zebra mussels. Differences in costs and body size imply differences in energy allocation that may be reflected in energy reserves. These differences are likely important factors in the competition. We focus on differences in metabolism and body composition of the quagga and zebra mussel population in western basin of Lake Erie sampled 6 times during June–September 2002.

Because of the importance of metabolism in the energy budget and the differences between species we examined metabolism further. We measured the activities of three enzymes involved in the aerobic and anaerobic metabolic process (citrate synthase, lactate dehydrogenase, and malate dehydrogenase). All three enzymes are indicators of the maximum capacity for production of ATP. Comparing enzyme activities is useful for understanding the different strategies each species uses to adapt to its environment such as: 1) differences in metabolic potential that may make one species more energy efficient thus influencing the species success in a habitat, and 2) whether or not one species is favored in low oxygen conditions. In addition, metabolic enzyme activity responds in hours to days thus providing important information about mussels' responses to changing environmental conditions.

Differences in body size between species may indicate differences in body composition and thus energy reserves. Energy reserves are factors of general condition that reflect energy allocation over longer periods of time. For example, low lipid and protein values may indicate an organism under stress. We measured lipid and protein content in zebra and quagga mussels to examine if differences in energy allocation exist that could be responsible for the quagga mussel success.

NOTES

Grazing of a Non-indigenous Species on Nuisance Organisms: Implications for the Use of Zebra Mussels in Biomanipulation

Miguel Dionisio Pires
Netherlands Institute of Ecology - Centre for Limnology, Department of Foodweb Studies
Rijksstraatweg 6, 3631 AC Nieuwersluis, The Netherlands
T: 31-294-23-93-09 F: 31-294-2- 22-24 E: m.dionisio@nioo.knaw.nl

Most lakes in the Netherlands are, despite several phosporus reducing measures, still highly turbid. This turbidity is mainly caused by high algal biomasses, especially of toxic cyanobacteria. One way of reducing the nuisance of cyanobacteria is by using grazers, which are capable of removing cyanobacteria from the water column.

In the Netherlands zebra mussels are not always considered as a harmful invader. It has been suggested to use them as a tool in the restoration of eutrophic systems by biomanipulation, because of their high filtering capacity.

In order to see if zebra mussels can be used in lake restoration programmes the feeding behaviour of the zebra mussel *Dreissena polymorpha* was studied using lake seston. Also zebra mussels were exposed to toxic *Microcystis* for one week in order to study the effects of exposure to microcystin on feeding behaviour of the mussels. Furthermore, mussels were exposed to different phytoplankton species to study survival.

Zebra mussels cleared all seston components at equal rates. Analysis of pseudofaeces, however, showed that especially detritus was expelled and cyanobacteria were ingested. When the seston was divided into size-classes, the zebra mussels again cleared all components at an equal rate. Analysis of pseudofaeces showed that particles between 3 and 30 µm, containing most cyanobacteria, were retained by the mussels. The feeding behaviour of the mussels was not affected by exposure to toxic *Microcystis*. No differences in survival of the mussels was observed between different food treatments. Mussels had no problems with the toxic cyanobacteria as compared to non-toxic cyanobacteria and green algae.

It is concluded that the presence of toxic cyanobacteria will not hinder the mussels in its filtration. The mussels could be useful aids in clearing lakes in the Netherlands from toxic cyanobacteria. Placing hard substrate as shells and stones that can be easily colonized by the mussels should overcome the limited availability of suitable substrate and this could aid water managers in reducing harmful algal blooms.

NOTES

Population Genetics and Invasive Risk Analysis of the Round Goby (*Neogobius melanostomus*) and the Tubenose Goby (*Proterorhinus marmoratus*)

Toriano A. Bowens *and Carol A. Stepien*
Great Lakes Environmental Genetics Laboratory, Cleveland State University
2121 Euclid Ave., MC 219, Cleveland, OH 44115 USA
T: 216-523-7488 F: 216-687-5393 E: t.a.bowens@csuohio.edu

Nonindigenous versus native population genetic structure are compared for the Eurasian round goby *Neogobius melanostomus* and tubenose goby *Proterorhinus marmoratus*. They invaded Lake St. Clair of the North American Great Lakes in 1990 from foreign ballast water. The round goby spread rapidly to all of the Great Lakes and the tubenose goby has just recently appeared in western Lake Erie. The genetic composition of an invasive population is believed to be important for its success. High variability may be predictive of invasive success in risk analysis, a hypothesis that is examined in our study. The present investigation expands previous work performed by another lab, which examined DNA sequence variation of the mitochondrial DNA cytochrome b gene. In addition, our laboratory will add new samples from other Eurasian and Great Lakes locations and sequence the entire cytochrome b gene, which will add more variation to the previous study. To date, we have sequenced the first tubenose goby samples from Eurasia, and round gobies from that site and another location. We also expanded the cytochrome b data set to include more samples of tubenose gobies from Lake St. Clair, and samples of round gobies from Lake Erie and five new Eurasian sites. In addition to the round and tubenose goby, our lab will sequence 10 additional *Gobiidae* species of Eurasian descent and perform a phylogenetic analysis. Results to date reveal greater genetic variation in the tubenose goby population from the Danube River than found in North America. The North American population of the tubenose goby appears to be monomorphic at the present time, and this low genetic diversity may be predictive of its slower spread. In contrast, there are a diverse number of haplotypes characterizing round goby populations in both North America and Eurasian sites, fitting the risk analysis prediction of high genetic variability in a successful introduction.

NOTES

An Overview of the Third International Conference on Marine Bioinvasions

Russell Moll
California Sea Grant College Program, University of California, San Diego
9500 Gilman Drive, Dept. 0232, La Jolla CA 92093-0232 USA
T: 858-534-4440 F: 858-534-2231 E: rmoll@ucsd.edu

This presentation is an overview of the salient issues discusses at the Third International Conference on Marine Bioinvasions was held in La Jolla, CA in March 2003. This three-day meeting covered a wide range of topics that included impacts to marine ecosystems from marine invasions, consideration of different types of transport vectors, patterns of marine invasions in space and time, management and assessment of marine invaders, economic impacts of marine invasions, policies concerning marine invasions, and innovative education and outreach programs surrounding marine invasions. Attendees at this popular meeting came from all over the globe and made more than sixty presentations and a similar number of posters were displayed. While the conference covered a wide range of topics, there was a particular interest in marine invasions on the west coast of North America. Special attention was given the to the case study of the invasion of California waters by *Caulerpa taxifolia* and the eradication program developed as a result by the state. While there was a west coast flavor to several of the presentations, and posters, overall the meeting provided a wealth of information on the general topic of marine bioinvasions.

NOTES

An Early Detection, Warning, and Assessment System for Coastal Marine Alien Species

***Donna D. Turgeon**, Michelle R. Harmon and Gary C. Matlock*
NOAA/NOS/National Centers for Coastal Ocean Science
1305 East West Highway, N/SCI, SSMC4, 8th Floor, Silver Spring, MD 20910 USA

Any organism introduced into a habitat other than the one in which it evolved has the potential to impact the entire ecosystem and be economically costly to control. Such species are considered "alien"; well-established populations are termed "invasive". Invasive species are second only to habitat destruction in causing biodiversity declines. Alien species affect all US regions and every nation in the world. In the US, there are an estimated 50 000 species responsible for at least $140 billion per year in environmental damages, losses, and control measures. The rapid global expansion of maritime trade (e.g., foreign ocean-borne trade is expected to double by 2020), hull fouling and ballast water releases, aquaculture practices, public and private aquarium releases, the use of exotic live bait, and scientific research have introduced alien species around the world.

Reversing the damage caused by invasive species requires attention to prevention, detection, assessment, and action. NOAA is building an early detection, warning, and assessment system to allow for action to reverse the trend of increasing alien species and, ultimately, rid US coastal waters of biological invaders. With contingency planning, timely warnings, and other information from this initiative, coastal managers can act to prevent future occurrences of alien species and mitigate existing species effects. Reducing the potential for an alien species becoming established in an ecosystem will help maintain the habitat structure and function as it has evolved, thus preserving biological diversity and providing coastal communities with protection from flooding and coastal storms. This system could even reduce the probability of protected species becoming extinct by preserving ecological niches for those organisms that have evolved over hundreds of thousands of years.

As early as FY08, US coastal states, territories, and the Pacific Freely Associated States could be protected by the envisioned system. The warning system began as a Hawaiian pilot project in FY02. The Hawaiian Pilot being tested in FY03 is an interactive website, linked to a peer-reviewed inventory of all coastal marine species, where managers can report the sighting of a new species and request species verification from taxonomic experts. They can also get integrated risk assessments on the likelihood of a species becoming invasive, map alien distributions, and download relevant environmental data. In the event that a specimen is verified as alien to a region, a warning will be posted automatically and the baseline database updated. In FY04, NOS will initiate a second Hawaiian Pilot that will be a model national early detection and assessment system.

Currently, agency and volunteer monitoring program data are being integrated and, where substantial gaps are detected, new monitoring with comparable protocols will be conducted. By FY05, monitoring of other regions will be added to the system.

There is broad political consensus for the need of such a system. The program's many partners will help assure the following programmatic outcomes. The occurrence of new invasive species will be reduced through monitoring and early detection of alien species. Existing invaders will be prevented from spreading to other geographic areas that may become available as a result of environmental factors such as climate change, excess nutrients, and over fishing. The system will be maintained in National Marine Sanctuaries, National Estuarine Research Reserves, coral reef ecosystems, and estuaries nationwide. Integrated risk assessments and forecasts will be prepared that predict the likelihood of particular alien species becoming invasive.

NOTES

Establishing a National Monitoring Programme for Marine Pests In New Zealand

Debra Wotton
Ministry of Fisheries, PO Box 1020, Wellington, New Zealand
T: 64-4-470-2595 F: 64-4-470-2669 E: debra.wotton@fish.govt.nz

Marine biosecurity is based on a risk-minimisation approach in which current and future risks are identified and acted upon. The most effective strategy for biosecurity controls is to focus on minimising non-indigenous species introductions. Because it is inevitable that some new species will arrive, biosecurity risk management requires reliable information on the nature and extent of these introductions. The New Zealand Ministry of Fisheries (MFish) has established a national monitoring programme to detect non-indigenous species introductions. The programme consists of three elements – port baseline surveys, targeted surveillance and a public surveillance network.

MFish has commissioned the National Institute of Water and Atmospheric Research (NIWA) to undertake baseline surveys of 14 of our major international ports to establish their current native and introduced biodiversity status. Ongoing monitoring of the ports will be designed to detect new introductions of non-indigenous marine species and simultaneously measure the effectiveness of border controls.

Ports were selected using a rigorous risk-based approach evaluating 6 factors, including volume of ballast water discharged and number of vessel arrivals. We do not currently know which factors contribute most to the risk of invasion. Results from the surveys will be used in conjunction with other data to enable identification and management of those factors that contribute to a high risk of incursion to New Zealand's ports.

MFish is also implementing regular surveillance for six identified high-risk species to enable early and rapid responses to incursions. These species were selected because they have a previous history of invasiveness, pathways exist that would enable them to arrive in New Zealand, and environmental conditions in New Zealand are suitable for their establishment.

The most effective surveillance strategy is to look in those locations where new species are most likely to arrive. The initial focus of the surveillance for these six high-risk species is in eight harbours that have a high likelihood of invasion based on their past history of invasions, current international shipping movements, the variety of habitats available, and restricted exchange of water with oceanic environments.

In addition, MFish has established a public surveillance network involving marine industries, divers, local and central government, and the public, which provides additional monitoring in a broad range of areas. Tools developed to facilitate public surveillance include identification guides of the six high-risk species for use by these groups.

NOTES

Invasive Species – Are We Winning the Management Battle?

Richard Gallant *and Neil MacNair*
PEI Fisheries, Aquaculture and Environment, P.O. Box 2000, Charlottetown, PE C1A 7N8 Canada
T: 902-368-5615 F: 902-368-5542 E: ngmacnair@gov.pe.ca

Three new species, the clubbed tunicate (Styela clava), the green crab (*Carcinus maenas*), and the oyster thief (*Codium fragile*) have been either accidently introduced or have invaded the waters of Prince Edward Island since 1997. These species are impacting PEI's $35 million shellfish industry. The PEI Department of Fisheries, Aquaculture and Environment has been conducting field research with the shellfish industry, other government and university partners to study the impact of the new invaders. Applied research is being supported to develop control measures and in some cases management plans have been implemented in an attempt to slow the spread of these invaders from infested areas to non-infested areas.

NOTES

Aquatic Nuisance Species Response in the Pacific Northwest

Stephen Phillips
Pacific States Marine Fisheries Commission, 45 SE 82nd Drive, Suite 100, Gladstone OR, 97207 USA
T: 503-650-5400 F: 650 5426 E: Stephen_Phillips@psmfc.org

Mark Sytsma
Center for Lakes and Reservoirs, Portland State University, Box 751, Portland, OR 97207-0751 USA

Beginning in 1999, the Bonneville Power Administration (BPA), recognizing the potential impact to its operations, funded the Pacific States Marine Fisheries Commission (PSMFC) and Portland State University to conduct an aquatic nuisance species (ANS) prevention program for the Columbia River Basin (CRB). Further funding has come from the US Fish and Wildlife Service Authorized by Congress in 1947. The Pacific States Marine Fisheries Commission (PSMFC) is dedicated to resolving fishery issues. Representing California, Oregon, Washington, Idaho, and Alaska, the PSMFC works closely with the Center for Lakes and Reservoirs (CLR) at Portland State University on aquatic nuisance species (ANS) management.

The objective of the PSMFC ANS Program is to prevent harm from ANS species to important commercial and recreational fisheries and the ecosystems upon which these fish depend. Program emphasis is on outreach and education to appropriate user groups, assisting states in the region develop ANS management plans, and funding and coordinating monitoring of species of concern.

Currently, the PSMFC program funds are directed at four species: zebra mussel (*Dreissena polymorpha*), Atlantic salmon (*Salmo salar*), European green crab (*Carcinus maenas*) and mitten crab (*Eriocheir* spp). The CLR program includes research on these species and on freshwater aquatic weeds, ANS surveys, management planning for spartina in Oregon estuaries, research on ballast water introductions of ANS, and implementation of the Oregon Aquatic Nuisance Species Management Plan.

Discharge of ships' ballast water offshore and at ports may be a significant pathway for ANS introduction (e.g., zebra mussels) to the West Coast of the United States. With differing coastal state and British Columbia port regulations for ballast water management, there is a clear need for enhanced coordination on the West Coast. The PSMFC assists in regional coordination of West Coast ballast issues with the Pacific Ballast Water Group. The Pacific Ballast Water Group was formed following a series of informal meetings of state (OR, WA, CA, AK) and federal agencies, shipping industry, and Canadian representatives concerned about the introduction of aquatic nuisance species through ballast water discharge.

NOTES

Managing Invasive Species at the Portal of North America: The Louisiana State Management Plan

Alysia R. Kravitz *and Richard Campanella*
Center for Bioenvironmental Research at Tulane and Xavier Universities
202 Alcee Fortier Hall, Tulane University, New Orleans, LA 70118 USA
T: 504-862-8441 F: 504-862-8455 Email: akravitz@tulane.edu

Mark G. McElroy
Louisiana Department of Wildlife and Fisheries, P.O. Box 98000, Baton Rouge, LA 70898 USA

Marilyn Barrett-O'Leary
Louisiana Sea Grant Program, 103 Sea Grant Building, Louisiana State University, Baton Rouge, LA 70803 USA

Lisa C. Schiavinato
Sea Grant Legal Program, 204 Sea Grant Building, Louisiana State University, Baton Rouge, LA 70803 USA

Geography renders Louisiana especially vulnerable to invasive species. The Bayou State possesses 40% of the contiguous United States' coastal wetlands, a humid subtropical environment, myriad waterways and highways, centuries-old cities, and the delta of North America's greatest river. It is also home to the nation's busiest port system, handling over a half-billion cargo tons annually—one-fifth of all shipments in and out of the United States. These features create an environment very suitable for new species introduction and establishment of many invasive plants and animals, including nutria, water hyacinth, Formosan termites, giant salvinia, zebra mussels, fire ants, and Asian tiger mosquitoes.

To combat the invasive species problem in Louisiana, Governor M.J. "Mike" Foster Jr. issued an Executive Order in June 2002 to create the Louisiana Aquatic Invasive Species Task Force, charging it to devise a management plan for the "prevention, control, containment, and/or eradication of non-indigenous aquatic species… within the state of Louisiana." The Governor appointed to the Task Force representatives from appropriate state agencies, some federal agencies, major universities, industry, and non-governmental organizations, designating the Louisiana Department of Wildlife and Fisheries as lead. This task force has since convened three times and has made substantial progress toward an effective and innovative state management plan. This paper reports on the current status of the Louisiana plan, problems encountered, lessons learned, and the future of invasive species management in Louisiana.

NOTES

Once Established, Can Zebra Mussels Be Eliminated? A Case Study From Lake George, New York

John Wimbush *and Sandra A. Nierzwicki-Bauer*
Darrin Fresh Water Institute, Rensselaer Polytechnic Institute, Bolton Landing, NY 12814 USA

Marc E. Frischer
Skidaway Institute of Oceanography, Savannah, GA 31411 USA
T: 518-644 3541. F: 518-644 3640 E: wimbuj@rpi.edu

Bioassays tell us that Lake George can support adult zebra mussels but not veligers. But when adults were discovered in December 1999 the evidence indicated that the adults had successfully recruited over the previous year or two.

Since Spring 2000, when 19 176 mussels were removed from the site, removal projects each spring and fall have seen diminishing numbers of mussels removed. Veliger monitoring through each summer and fall has found no evidence of veligers.

Experience at this site points to the possibility that, given favorable conditions and an aggressive mitigation effort, it may be possible to eliminate localized populations of zebra mussels.

NOTES

The Eurasian Watermilfoil Controversy in Lake George, NY: The Interplay Between Science, Policy and Public Concern

***Charles W. Boylen**, Jeffrey Bartkowski, and Lawrence W. Eichler*
Darrin Fresh Water Institute and Rensselaer Polytechnic Institute, Troy, NY 12180-3590 USA
T: 518-276-8430 F: 518-276-2162 E: boylec@rpi.edu

The introduction of *Myriophyllum spicatum*, the Eurasian watermilfoil, into lake George, NY just prior to 1985 has had a profound impact on native plant species. Although we have maintained an exhaustive program to limit its spread since 1988, approximately 6–15 new sites are discovered yearly. Presently over 140 locations have been found within the 192-mile shoreline encompassing the littoral zone. Lake George is a deep, oligotrophic lake in the southeast corner of the Adirondacks. While some locations only support limited growth of milfoil, others harbor nearly mono-specific beds covering several acres of lake bottom, decimating the native plant community. Current selective management strategies include hand harvesting, suction harvesting and benthic barrier. Because the plant can grow as deep as 6 m in the lake, mechanical harvesting has not been considered a viable alternative. For several years the Lake George Park Commission (a regulatory agency whose director is appointed by the governor) and the Lake George Association (an association of residents and stakeholders) have lobbied for the experimental treatment of Sonar at select sites. Although the state's Department of Environmental Conservation has approved the use of Sonar in New York State, the 2800 lakes and ponded waters of the Adirondack Park are regulated by the Adirondack Park Agency (whose director is also appointed by the governor). Repeated requests to allow select treatment in Lake George have been unsuccessful, including a lengthy adjudicatry hearing pitting state regulatory agencies against one another. Expert scientific and management testimony carried less weight than emotional attitudes against chemicals. A main question arises as to where does scientific reasoning come into play.

NOTES

Invasion of the Aquatic Plant, *Cabomba caroliniana* in Canada. Research at Kasshabog Lake in Peterborough, Ontario

Jennifer Noel
Watershed Ecology Graduate Program, Trent University, 1600 West Bank Drive, Peterborough, ON K9J 7B8 Canada
T: 705-748-1011 x 5365 F: 705-748-1026 E: jnoel@trentu.ca

Studies of *Cabomba caroliniana* in Kasshabog Lake, were conducted from the summer of 2001 to the fall 2002, where it has established for the first time in Canada. The importation of *C. caroliniana* for the aquarium business is not regulated in Canada. This aquatic plant is native to the subtropical southeastern United States, thus would not be expected to survive in Canadian climate. At present, Kasshabog Lake and the North River, which serves as the outlet for the lake, are the only areas known to contain this plant species, where lake users deem it a nuisance. In areas where it is well established, density is as such that movement by watercraft through a stand is almost impossible. This is one of many concerns faced by communities and organizations of neighboring waterways. Little is known about the growth and reproduction patterns of *C. caroliniana* outside of the native range. Seed germination and seedbank experiments were conducted to determine the main mode of reproduction. Plant samples were collected each month in June through October from five bays within Kasshabog Lake, to determine the productivity of *C. caroliniana*. In addition, limnological measurements were taken in four of the five bays to gain a better understanding of the habitat. The germination experiment suggests that *C. caroliniana* does not reproduce sexually even though seeds are produced. The seedbank experiment further confirms that the seeds are not viable since plants that were found came from minute fragments that existed within the sediment. This plant has greater density and distribution than native plants found within the lake. The growth curve peaks in the end of September when most plants have started to senesce. This has management implications by both the lack of sexual reproduction and the seasonality of the plant for the timing of control measures.

NOTES

The Oregon Spartina Response Plan

***Mark Sytsma**, Mary Pfauth and Dennis Issacson*
Center for Lakes and Reservoirs, Portland State University, PO Box 751, Portland OR 97207 USA
T: 503-725-3833 F: 503-725-383 E: sytsmam@pdx.edu

Introduced *Spartina* species are a major threat to Oregon estuaries, where they invade tidal mudflats. The thick stems of invasive *Spartina* decrease tidal flow velocity and increase sedimentation that can eventually raise the mudflat elevation above the intertidal zone. The change from open mudflats to vegetated salt marsh can have severe impacts on invertebrates, fish, and shorebirds. Restoration of hydrology and habitat of estuaries having extensive areas of established *Spartina* has not been accomplished, although such efforts are underway at Willapa Bay, Washington.

The only known occurrence of *Spartina* in Oregon is in the Siuslaw estuary. An infestation of *S. alterniflora* was eradicated by the Oregon Department of Agriculture and a population of *S. patens* is under active control by The Nature Conservancy on Cox Island. Other estuaries in the state are also vulnerable to invasion by *Spartina*

A rapid and effective response to a new infestation of *Spartina* in Oregon is necessary to prevent the likely irreversible damage caused by massive Spartina invasion. The *Spartina* Response Plan for the State of Oregon was developed in response to this threat. The plan has three major goals: early detection of pioneer populations; rapid, coordinated response; and adequate follow-up to prevent reinfestation. The plan includes survey protocols for early detection of *Spartina*, recommendations for infestation-scaled response, and identifies potential obstacles to management.

NOTES

Long-Range Movement of Invasive Aquatic Plants Through Water Garden Trade

Kristine Maki *and Susan Galatowitsch*
University of Minnesota, Department of Horticultural Science, 305 Alderman Hall, 1970 Folwell Ave., St. Paul, MN 55108 USA
T: 715-634-0102 E: gies0038@umn.edu

The popularity of the water garden industry and the ease of ordering have increased the movement of plants beyond ranges achieved through natural dispersal. The extent to which movement of invasive aquatic plants across the United States occurs through accidental inclusion in plant orders or sale of prohibited species is not known. To determine the prevalence of invasive aquatic plant movement into Minnesota, forty aquatic plant orders, totaling 123 taxa and 681 individual plants, were placed from 34 vendors across the United States. Orders were inspected for receipt of ordered federal noxious weeds or Minnesota prohibited exotic species, plants not ordered, presence of seeds, and mis-identification of plants. Federal noxious weeds or Minnesota prohibited exotic species were acquired 92% of the time they were ordered and included *Alternanthera sessilis, Butomus umbellata, Hydrocharis morsus-ranae, Potamogeton crispus*, and *Lythrum salicaria*. Ninety percent of orders received included a plant species that was not specifically ordered; 10% of these purchases contained federal noxious weeds or Minnesota prohibited exotic species. *Lemna minor* was the most common incidental receipt found, although *Hydrilla verticillata, Lythrum salicaria, Salvinia molesta*, and *Potamogeton crispus* (all prohibited taxa) were also found. Mis-identified plants were found in 15% of orders; unordered seeds in 41%. The sale and transport of prohibited and noxious aquatic plants likely presents the greatest risk associated with the water garden trade. Increased risk of noxious plant or prohibited species movement is also associated with misidentification leading to sale of invasives and the incidental inclusion of species in plant orders. The movement of noxious plants through this pathway has the potential to increase the rate and geographic spread of invasive aquatic plants.

NOTES

Development of Early Detection Guidance and a Model Rapid Response Plan in the Great Lakes: Issues, Need and Approach

Katherine Glassner-Shwayder and ***Sarah Whitney***
Great Lakes Commission, 2805 South Industrial Hwy., Suite #100, Ann Arbor, MI 48104 USA
T: 734-971-9135 F: 734-665-4370 E: swhitney@glc.org

Approximately 160 nonindigenous aquatic invasive species have become established in the Great Lakes system since the middle of the 19th century. Once established, controlling the spread of these species is both technically difficult and expensive. Control efforts for purple loosestrife, zebra mussels and sea lamprey alone have been assessed at $365 million per year on a national scale. Eradication/control of NIS populations has a higher likelihood of success if nuisance species are detected soon after introduction, at which point the number of individuals in the NIS population is low and eradication/control measures can be applied quickly and in a targeted manner.

Currently, the infrastructure for early detection and rapid response has not been established to control NIS introduction and spread in the Great Lakes region. The Great Lakes Commission, in conjunction with the Great Lakes Panel on Aquatic Nuisance Species, has undertaken the development of guidelines and recommendations for early detection and development of a model rapid response plan for the region.

A number of questions must be answered in order to develop usable guidelines for early detection and an effective rapid response plan, including: How should monitoring for early detection be conducted? How can baseline data be utilized to reflect disturbances caused by NIS impacts? How should rapid response plans be structured to respond to NIS introductions and spread in a time frame that can maximize the possibility for eradication/control? How can rapid response plans be structured to avoid institutional/jurisdictional obstacles that might impede action within a reasonable time frame?

The recommendations for early detection and monitoring will focus on what needs to be done to develop a coordinated system to detect new invasions of nonindigenous aquatic species in the Lake Michigan basin. The guidelines are specifically focused on the Lake Michigan basin to take advantage of the monitoring inventory efforts developed by the Lake Michigan Monitoring Coordination Council, but may also provide the base for a comprehensive regional early detection and monitoring system in the Great Lakes-St. Lawrence ecosystem. The guidelines and recommendations will be developed based on an assessment of existing monitoring coverage in the basin, a determination of the capacity of existing monitoring efforts to discover new NIS introductions and track the spread of current NIS.

In order to begin development of the model rapid response plan, a thorough review of the literature was conducted. The literature review, as well as discussion with the Great Lakes Panel, helped outline a framework for the model and identify its components. Once consensus was reach on the components, a mid-project workshop was held to develop and fill out each component. The next step is for the model plan to be made operational. A test case, where a new species is found in a specific location, will actually be conducted based on the model plan to determine gaps and unmet needs as well as identifying redundancies in the plan.

NOTES

River To River Project: Great Lakes United and École Instrument de Paix (EIP), Niger

Sylvie Trudel
Great Lakes United, 4525 de Rouen, Montréal, QC HIV 1H1 Canada
T: 514-396-333 F: 514-396-0297 E: sylvie@glu.org

The River to River Project is an environmental education pilot project on the Niger River and involves the participation of organized groups from the Kandadji, Dessa and Bonfeba communities. The project uses the issue of invasive water hyacinths as the central theme for environmental education, social change, and local economic development for communities struggling with critical survival and environmental problems.

The water hyacinth (*Eichhornia crassipes*) is considered to be one of the most destructive aquatic plants in the world. Native to the Amazon basin, the water hyacinth has spread worldwide in the last 100 years. Traded and shipped as an ornamental plant for water gardens, the water hyacinth rapidly escapes and invades marshes and waterways.

The plant reproduces mainly by cloning, but its seeds also play a role in its survival and colonization. It can infest areas quickest if the balance of the ecosystem has been upset by human activity: i.e., installation of dikes, dams and canals

The plant outcompetes other aquatic plant life and often causes eutrophication of waterways. Water hyacinths dramatically reduce biodiversity by affecting water chemistry and fish populations.

Water hyacinths also severely impacts human activity. It invades rice paddies and blocks the turbines of hydroelectric and water filtration plants and pumping stations. The plant can also be dangerous to human health. It allows diseases such as schistosomiasis and malaria (larvae) to spread. Water hyacinth tufts also provide protection for potentially harmful species such as snakes and leeches.

In Niger, water hyacinths have invaded the country's only waterway, the Niger River. As a result, Great Lakes United and École Instrument de Paix developed this pilot project around recycling and using the water hyacinth as an organic resource. This method of localized invasive plant control fuels economic development for three villages.

Composting water hyacinths made it possible to a) enrich sandy soils with organic matter; b) double the women's produce output; c) nourish plants in nurseries intended for reforestation d) fertilize reforested plants.

The plant filters and purifies water. Filtration basins had already been constructed to provide people on the island of Kandadji with drinking water.

Local women dry the stems of the hyacinth and make handicraft articles such as mats, baskets and winnowing-basket shovels.

As an alternative to firewood and charcoal, the hyacinth is dried and compressed into briquets that are used for cooking food.

The water hyacinth is used in manufacturing artisanal paper.

NOTES

Pathogen Organisms Arriving from Ships' Ballast Water in Cartagena Bay

Silvia Rocío Rondon
Centro de investigaciones Oceanograficas e Hidrograficas (CIOH), División de Estudios Ambientales
Escuela Naval Almirante Padilla, Isla Manzanillo, Cartagena, Colombia
T: 57-5-6694104 F: 57-5-6694297 E: srondon@cioh.org.co

Considering that several species of bacteria, plants and animals can survive in the ballast waters transported by ships and the role of ballast water as a mean for propagating bacteria casing epidemics, a research study was initiated to identify the species of organisms present in this type of waters arriving in the Cartagena Bay. The analysis of pathogen bacteria, phytoplankton and zooplankton was made in the samples from ballast water tanks.

The samples were screened for the presence of *Vibrio cholerae* selecting yellow colonies on TCBS agar and performing the arginine dihydrolase and esculin hydrolysis tests using purified isolates. Isolates giving negative reactions in the both of the tests was presumptively considered *V. Cholerae*.

This research is the first study in ballast water in Colombia and is the first step to adequately define of the nature and extent of the problem in the country to develop in the future control and preventive measures.

NOTES

Evaluations of Deoxygenation as a Ballast Water Treatment to Prevent Aquatic Invasions and Ship Corrosion

Mario N. Tamburri
Alliance for Coastal Technologies, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science
PO Box 38, One Williams Street, Solomons, MD 20688 USA
T: 410-326-7440 F: 410-326-7428 E: tamburri@cbl.umces.edu

Peter D. McNulty
NEI Treatment Systems, Inc., 900 S. Serrano Avenue, Suite 701, Los Angeles, CA 90006 USA

Brenda J. Little
Naval Research Laboratory, Stennis Space Center

Gregory M. Ruiz
Smithsonian Environmental Research Center, 647 Contees Wharf Road, P.O. Box 28, Edgewater, MD 20910 USA

One of the most important mechanisms for the introduction of aquatic nuisance species is transport in ship ballast waters. Although several ballast tank treatments to prevent transport of aquatic organisms appear promising, all existing approaches will result in significant costs to the shipping industry. The implementation of ballast water treatment measures would be hastened by providing the shipping industry with economic incentives for doing so. Our initial work suggests that deoxygenation may be such a treatment with benefit for ship owners by reducing corrosion, while simultaneously limiting the number of aquatic organisms surviving transport in ballast tanks.

Purging of oxygen from ballast tanks with nitrogen gas was recently proposed by Sumitomo Heavy Industries to be a cost-effective technique for reducing corrosion and therefore extending ship life. An initial shipboard study found a 10-fold reduction in corrosion rates under hypoxic ballast tank conditions. In previous studies, we also tested both the oxygen tolerance of larvae from known invasive invertebrate species and conducted literature reviews on the ability of aquatic organisms to survive low oxygen environments. These investigations suggest that few organisms will be able to withstand extended periods of exposure to hypoxic ballast water.

While initial results are promising, several questions must be addressed before definitive conclusions can be drawn regarding the feasibility of deoxygenation as a ballast water treatment. In particular, issues of cost effectiveness, responses of natural planktonic communities, microbiologically influenced corrosion, and scaling up to shipboard applications require additional investigations.

We will discuss the potential of deoxygenation to prevent both invasions and corrosion by briefly reviewing our past work and reporting on our current investigations to: 1) optimize the oxygen stripping process (with particular emphasis on the ballasting flow rates and tank volumes of large vessels); 2) determine mortality levels of natural Chesapeake Bay planktonic communities (zooplankton, phytoplankton, and microbes) under hypoxia in mesocosm experiments; and 3) quantify corrosion rates and establish the mechanisms under deoxygenated conditions (with particular emphasis on microbiologically influenced corrosion). These steps will ultimately lead to a full-scale study to determine the efficacy of deoxygenation at removing ballast water organisms onboard active vessels.

NOTES

Deoxygenating Ballast Water Using a Dry Biomass Process: A New Technique to Treat Ballast Water to Reduce Aquatic Invasive Species Transfer

Michel DeBlois
Polygo Inc., 1210 Curé Poirier est, suite 505, Longueuil, QC J4J 5J2 Canada
T: 418-828-1500 F: 418-828-1357 E: avalois@videotron.ca

Yves de Lafontaine
Environment Canada, Centre Saint-Laurent, 105 McGill St., Montreal, QC H2Y 2E7 Canada

Following the suggestion by Tamburri et al. (2002) that deoxygenating ballast water may be an effective treatment method to minimize the risk of transferring invasive aquatic organisms, we developed and conducted preliminary testing of a new technology capable of generating rapid oxygen depletion and inducing significant mortality of organisms in ballast water tanks. The method is based on a biological process using dry multi-species biomass which rapidly depletes dissolved oxygen once in water solution. Preliminary tests done on large volumes of St. Lawrence River water showed that oxygen levels dropped from 12 mg/L to 0 mg/L in less than 24 hours. The effectiveness of this method is temperature-dependent and can yield significant positive results between 5 °C and 35°C. This technology is environmentally safe and could be easily implemented on board ships. Further testing conducted at pilot-scale is planned for assessing the application of this technology for ballast water treatment.

NOTES

Large-Scale Testing of Hydrocyclone, Screen and UV Radiation as Ballast Water Treatment Technologies

***Junko Kazumi**, T.D. Waite and N. Zurcher*
College of Engineering, University of Miami, 1251 Memorial Drive, Coral Gables, FL 33146 USA
T: 305-284-2908 F: 305-284-2885 E: jkazumi@miami.edu

L.L. Farmer
College of Arts and Sciences, University of Miami, 1301 Memorial Drive, Coral Gables, FL 33146 USA

P.V.Z. Lane, S.G. Smith, S.L. Smith, G. Hitchcock and T.R. Capo
Rosenstiel School of Marine and Atmospheric Science, University of Miami
4600 Rickenbacker Causeway, Miami, FL 33149 USA

Large-scale dockside experiments were undertaken to evaluate the treatment efficiency of commercially available unit processes for preventing the transfer of unwanted species via ships' ballast water. The project was undertaken with funds from the US Coast Guard Research and Development Center, and the treatment system was built at the University of Miami's Rosenstiel School of Marine and Atmospheric Science campus. The test water from Biscayne Bay, Florida, was pumped through the system at approximately 5.7 m^3 min^{-1} (1500 gpm or gallons per minute). The unit processes included a hydrocyclone (centrifugal force of approximately 13 X g at 5.7 m^3 min^{-1}), a self-cleaning 50 µm (micron) screen, and a UV (ultraviolet) treatment unit (100% transmittance = 60 000 µW s cm^{-2}). In addition to these unit processes, a mixing system, including a high pressure injection pump, was fabricated to add suspended solids (clay slurry) to the flowing Biscayne Bay water to enhance turbidity. The effect of increased suspended solids and enhanced water color on the unit processes was the main focus of this research.

A broad spectrum of biological and biochemical indices were monitored to evaluate treatment efficiency. During each experimental run, 760 L (200 gal) samples were collected and passed through 35 µm plankton nets for zooplankton collection. Water samples were also collected for phytoplankton, microbiological, ATP and protein analyses. After the initial samples were collected, a second set of samples was held for 18 hours (turbidity experiments) or 6 to 7 days (color experiments) to determine the effects of storage on the effectiveness of treatment processes. Statistical analyses showed that hydrocyclonic separation was not effective for treatment. The 50 mm screen, however, was effective at removing over 90% of the zooplankton species monitored, and a small percentage of the microphytoplankton in the natural water samples. Initially, UV treatment was able to reduce the count of viable microorganisms to an undetectable level; however, bacterial regrowth was observed in samples held for 18 hours. There was no regrowth in samples held for 6 to 7 days.

The main variable explored in this research was the effect of increased suspended solids (turbidity) or enhanced color on the unit processes. While the dose delivered by the UV system decreased due to the increased suspended solids loading, its reduced value (approximately 25 000 µW s cm^{-2} minimum dosage) was still sufficient to inactivate microorganisms, even with the increased turbidity. In subsequent experiments, a UV dose of 10 000 µW s cm^{-2} was found to be insufficient to inactivate microorganisms.

In general, it was observed that only the 50 mm screen contributed appreciably to removal of organisms, especially zooplankton in the test water of this facility. If organisms smaller than 50 mm are to be removed or killed however, then either a more efficient filtration process or a biocide will need to be added to achieve these treatment goals. It appears that UV treatment will not be effective at facilitating any meaningful treatment, especially against potential invading organisms such as large zooplankton or larvae of invertebrates.

Ship Ballast Water Treatment: The Closed-Loop Option

Paul Brodie
Balaena Dynamics Ltd.

Chip Blatchley
Purdue University

Mary Balcer
The University of Wisconsin

Yoel Sasson
The Hebrew University of Jerusalem

Itay Kreisel, Danny Sorek and Niv Shimron
Arkal Filtrations Systems

***Bill Cairns** and Ron Braun*
Trojan Technologies Inc., 3020 Gore Road, London, ON N5V 4T7
T: 519-57-3400 F: 519-457-3030 E: bcairns@trojanuv.com

A new Ballast Water Treatment (BWT) process option is presented that is potentially advantageous when applied to any number of treatment process configurations, but especially advantageous when used in processes that involve UV-based treatment. The new process option, the use of closed-loop treatment while in transit, is examined for its compatibility with a set of BWT process selection criteria, design options and strategic considerations that are outlined in the paper. The primary advantage of the closed-loop option when used with UV technologies is the ability to accommodate low water qualities in the equipment design without having to size the treatment technology to address the worst case water quality in a single pass. Advantage is taken of the in-transit time to build UV dose to whatever level is specified in the process design. En route treatment also takes advantage of the power availability. The closed-loop option configuration has the flexibility of being used in a single pass process when water quality permits, in a dual pass (ballasting and deballasting) when in-transit growth of organisms is a problem, in the patented closed-loop option while in transit from port to port when the ballast water quality is poor, and is compatible with Ballast Water Exchange (BWE) where it is deemed practicable and safe. The closed-loop process option is also examined for its potential to manage ballast tank sediments.

NOTES

The Natural Ballast Water Exchange Method

Richard Whittaker
Teekay Shipping Canada Ltd., Suite 2000, 550 Burrard Street, Vancouver, B.C. V6C 2K2 Canada
T: 604-609-4774 F: 604-844-6650 E: richard.whitakker@teekay.com

The United States, Canada, Australia, and New Zealand have led the way by adopting strict guidelines for ballast water exchange, and the rest of the international shipping community is rallying to combat the threat of biological pollution. In fact, the International Maritime Organization (IMO) passed a resolution in November 1997 that identifies two methods for ballast water exchange: the sequential and flow-through methods. Both methods protect the aquatic environment but require a considerable amount of fuel and staff time.

When the sequential method is used, water is pumped out of the ballast tank until suction is lost and clean ballast water is pumped in. The flow-through method involves pumping ballast water into the tank until the dirty water overflows through the openings on top of the ballast water tank. Both methods rely on the use of an electric or steam-driven ballast pump and a diesel generator or a boiler. Careful monitoring of deballasting and ballasting operations is essential, and both methods create extra work for the duty engineer.

The Natural Ballast Water Exchange method takes into consideration the well-being of seafarers and the environment. The method relies on natural forces of pressure and gravity to achieve ballast water exchange. Unlike the sequential and flow-through methods, the new method does not require extra personnel to operate and monitor auxiliary machinery. Instead, clean water enters the ballast tank main line through a water inlet at the ship's bow. The pressure from the water flowing into the tank forces the biologically tainted water out through an opening located at the forward bottom end of the ballast water tank. To complete the operation, a limited amount of power is required to pump in enough clean ballast water to meet the initial water level.

When the ship is in forward motion, the pressure of the water acting on the hull is greater than the pressure of the water in the ballast tank. Simply put, this process uses the pressure differential to force the ballast water from the ballast tank, thereby replacing the water automatically. Overall, the new method saves on fuel costs and offers certain safety advantages.

NOTES

Kill Harmful Microorganisms in Ships' Ballast Water Using Hydroxyl Radical

Mingdong Bai, *Xiaojian Zhou, Xiyao Bai, Bo Yang and Xinjun Shen*
Environmental Engineering Research Institute, Dalian Maritime University, Dalian 116026, Liaoning, P. R. China
E: hjs@dlmu.edu.cn

A physics method is studied that the electrons are accelerated and then the gas molecules are aroused using a strong dielectric barrier discharge. With this method, the strong electric field ($E_d \geq 400$Td, 1Td=10^{-17}Vcm^2) is formed with the thinner α-Al_2O_3 dielectric layer in the narrow discharge gap at a high pressure (P≥0.1Mpa or n=2.6×10^{-19}/cm^3). The electrons achieve the average energy of above 12eV. The ionization potential of O_2 and H_2O molecules is12.5 eV and 12.6eV respectively. The ionization numbers of O_2 in strong ionization discharge is 12 769 times higher than that of O_2 in other gas ionization discharge at normal pressure. As a result, O_2 in air and H_2O in seawater are ionized and dissociated into a number of activate particles such as OH, O_2^+, O (^{1}D), HO_2 radical and so on. High dissolved hydroxyl radical (OH*) concentration of more than 10mg/L is achieved by the activate particles dissolved into seawater (a part of ballast water) with high mass transfer efficiency. 1.0 t dissolved hydroxyl radical is enough to treat about 10.0 t ballast water. The hydroxyl radical is a "green" ideal medicament without any toxin and residues, which is possible to be decomposed into H_2O and O_2 after 20 minutes.

The principles of organisms killed by hydroxyl radical are as follows:

1) Oxidization and decomposition of amino acids of introduced organism. The activated groups such as -OH, -NH_2 guanidino etc in amino acids of protein play an important action on maintaining proteinic configuration and catalytic activity of enzyme. When the hydroxyl radicals react with the activated groups, the chemical damage of protein further the death of introduced organisms occur.
2) The hydroxyl radical reacts with Deoxyribonucleic Acid (DNA) to produce DNA adducts resulting in a chemical damage without any restoration.
3) Hydroxyl radicals acts on the lateral chain of phosphatide polyunsaturated fatty acid of cell membrane to lead to the fast degradation of polyunsaturated fatty acid further to the damage of cellularity and then to cells death. In a world, the hydroxyl radical has a broad-spectrum deadly characteristic that is possible to kill microorganisms meanwhile bleaching and deodorization. The hydroxyl radicals act on the introduced microorganisms belonging to a dissociative radical reaction with a fast reaction rate.

When the dissolved hydroxyl ratio concentration is 0.15mg/L, the kill efficiency of bacteria sum is 99%. When the ratio concentration is 0.25mg/L, the kill efficiency of bacteria sum reaches 100%. After 5 minters of reaction, the hydroxyl ratio concentration to kill Ba. *Navicula*, Ch. *Dunaliella*, P. *Subcordiformis* is in range of 0.6~0.8 mg/L respectively, and the kill efficiency is above 99.0%. When the ratio concentration is 0.9 mg/L, 1.16mg/L, 1.12mg/L, the kill efficiency reaches 100%. The algae chlorophyll-a change after 24 hours of hydroxyl reaction is shown in Fig.4. The hydroxyl ratio concentration of suppressing chlorophyll-a increase is in the range of 0.21~0.34mg/L, the ratio concentration of all chlorophyll-a decomposed is in the range of 0.55~0.68mg/L. Therefore the dissolved hydroxyl value to kill microorganisms is 0.8mg/L.

NOTES

Using Barriers as an Alternative Sea Lamprey Control Method: A Summary of the Design Process

Timothy Watkins *and Natalie Dingledine*
DLZ Michigan, Inc., 1425 Keystone Ave. Lansing, MI 48911 USA
T: 517-393-6800 F: 517-272-7390 E: twatkins@dlz.com

The sea lamprey (*Petromyzon marinus*) is an exotic species that has had a dramatic negative impact on Great Lakes fish populations. During its adult life as a parasite, each lamprey can kill an estimated 40 lbs or more of Great Lakes fish. The Great Lakes Fishery Commission (GLFC) was formed in 1955 in part to control sea lampreys. The Commission, in cooperation with the Department of Fisheries and Oceans Canada, the US Fish and Wildlife Service (USFWS), and the US Army Corps of Engineers (Corps) all play a role in sea lamprey control on the Great Lakes. Control methods include lampricide treatments, trapping, a sterile male program and construction of barriers. Barriers provide a means to reduce or eliminate the use of lampricide by preventing the upstream migration of spawning lampreys. Barrier types include velocity, electrical, fixed-crest, and variable-crest barriers. The Corps of Engineers is assisting the GLFC with planning, design and construction of lamprey barriers under authority of Section 1135 of the Water Resources Development Act (WRDA) of 1986 for improving environmental quality and fisheries. The Corps planning and design process consists of a three-phases: the Preliminary Restoration Plan (PRP) Phase, the Planning & Design Analysis (PDA) Phase, and the Construction Phase. The PRP phase report serves as the initial decision document that identifies the Federal interest in completing the project. The PDA phase encompasses all planning and design work necessary to award a construction contract. Early in project development, extensive coordination with state fisheries and USFWS personnel helps to identify the preferred barrier location and type, and the need for fish passage. Factors used to determine location of barrier placement include site access, bank height and sea lamprey spawning locations. Various factors affect the type of barrier selected including risk of lamprey escaping, fish passage and cost. Detailed hydraulic analyses determine proper barrier height and resultant flooding with final barrier heights being selected according to risk criteria developed by the USFWS and DFO. Fish passage considerations are currently being met by using a vertical slot fishway with lamprey and fish traps incorporated into the design. The final barrier design is a result of collaborative efforts, which ultimately meet the requirements identified during resource agency coordination and reach the goal of efficiently stopping migrating sea lampreys while minimizing environmental impacts.

NOTES

Utilization of Benthic Barrier (Mats) to Eradicate Localized Zebra Mussel (*Dreissena polymorpha*) Infestations: Laboratory Bioassays and Field Studies in Saratoga Lake, New York

Shary Braithwaite *and Sandra A. Nierzwicki-Bauer*
Department of Biology, Darrin Fresh Water Institute and Rensselaer Polytechnic Institute
110 8th Street, Troy, NY 12180-3590 USA
T: 518-644-3541 F: 518-644-3640 E: nierzs@rpi.edu

John Wimbush and Geoff Sowan
Darrin Fresh Water Institute, 5060 Lakeshore Drive, Bolton Landing NY 12814 USA

Marc E. Frischer
Skidaway Institute of Oceanography, 10 Ocean Science Circle, Savannah, GA 31411 USA

While there are a number of zebra mussel control technologies that are routinely used in industrial settings, management of zebra mussels within freshwater bodies is more complex. The negative impacts of zebra mussels on aquatic ecosystems are well recognized; however, little progress has been made in the identification of eradication strategies in freshwater bodies. In the present study laboratory bioassays and field trials were carried out to investigate the potential usefulness of benthic mat coverings, which have been effectively used to control invasive aquatic vegetation, to eradicate localized zebra mussel populations.

Preliminary laboratory bioassays carried out in aquaria demonstrated that benthic mat covering of zebra mussels for 2 weeks resulted in mortality rates of 14.9–100%, compared with mortality rates of 0–2.2% in uncovered controls. In bioassay studies in which mussels were covered for 4 weeks mortality rates of 20–100% were observed. Mortality rates did not vary significantly with duration of covering or size class. To examine probable causes for increased mortality in mat-covered zebra mussels, several water chemistry parameters beneath mats, including dissolved oxygen, ammonia, calcium and magnesium and pH were measured. Dissolved oxygen concentration was the only parameter to exhibit both significant change and a consistent trend over the course of the experiment, declining from ~100% saturation to a mean of 16.5% saturation (SD=8.9%) and remaining at this level for the duration of the experiment.

In field studies carried out in Saratoga Lake, a small eutrophic lake in New York, SCUBA divers established treatment and control zebra mussel colonies at 2m depths on a rocky substrate. Rocks with attached mussels were randomly distributed on fiberglass screens placed on prepared gravel beds. In the initial pilot study divers placed 1m2 mats over 6 treatment colonies, each containing ~250–500 mussels. In a large-scale field trial 2 treatment colonies, comprising ~30 000 mussels each, were covered with 4m^2 mats. Mat edges were sealed tightly against the prepared beds with beach gravel to restrict water flow under the mats. Following 9 weeks of covering, mortality rates exceeded 99% in all covered treatments. As observed in the laboratory bioassays, large declines in dissolved oxygen concentrations occurred *in situ* under the mats, correlating strongly with increased mortality ($p<0.001$). Dissolved oxygen concentrations consistently fell from ~99% saturation to 5–38% (mean=14.6%+- 5.1%) saturation within 12–16 hours, after which levels remained in this range over the course of the covering treatment.

Benthic mat covering could potentially be used to eradicate localized zebra mussel colonies in water bodies where mussel populations are well established. However, the most promising potential application may be in sites where large populations have not yet developed. For example, Wimbush et al. (2002) have documented a potentially successful eradication of a zebra mussel population in Lake George, NY, via an intensive SCUBA hand-removal program. Benthic mat application could extend and reduce the labor intensity of such a program, and could represent a highly effective tool for the eradication of new zebra mussel infestations.

Aquatic Nuisance Species: An Evaluation of Barriers for Preventing the Spread of Bighead Carp to the Great Lakes

Ronald M. Taylor *and Mark A. Pegg*
Illinois River Biological Station, Illinois Natural History Survey,, 704 North Schrader Avenue, Havana, IL 62644 USA
T: 309-543-6000 F: 309-543-2105 E: taylorrm@staff.uiuc.edu

John H. Chick
Great Rivers Field Station, Illinois Natural History Survey, 8450 Montclair Avenue, Brighton, IL 62012 USA

The negative impacts of non-native fish species on the ecosystems and economies in which they become established is of growing concern throughout much of the world. Once a species is established in a system, management and control can quickly become cost-inhibitive. This problem is exacerbated in rivers that act as conduits of transportation to other aquatic ecosystems. Therefore, identifying potential mechanisms to control the range expansions of non-native fishes is imperative. For example, bighead carp *Hypophthalmichthys nobilis* and silver carp *Hypophthalmichthys molitrix* have continued to spread throughout the Mississippi River Basin since their first collection from the Mississippi, Ohio and Illinois rivers in the 1980s. There are now reproducing and rapidly expanding populations of bighead and silver carp in portions of the Mississippi, Missouri, Ohio, and Illinois rivers. These two invasive fish species will most likely enter the Great Lakes in large numbers if nothing is done to halt their upstream spread. The introduction of bighead and silver carp to the Great Lakes poses a potentially serious threat to the ecology of these systems as both of these fish species filter and consume plankton. Concern arises in that all species of fish consume plankton at some point during their lives and therefore may be affected by increased competition for food resources. Consequently, the use of behavioral fish guidance systems to deter these invaders from entering regions where their presence is unwanted has generated considerable interest. We evaluated the effectiveness of three behavioral fish guidance systems in restraining the movements of bighead carp in outdoor experimental raceways. The first system evaluated was a Sound Projection Array driven BioAcoustic Fish Fence (SPA driven BAFF). The second system we evaluated was a Sound Projection Array driven BioAcoustic Fish Fence (SPA driven BAFF) integrated with a Graduated Electric Field Barrier (GEFB). The third system we evaluated was a Graduated Electric Field barrier (GEFB). A given experiment involving the use of a specific guidance system (e.g., SPA driven BAFF) consisted of three trials. Each trial was three days in duration. On a given day, the movements of 11 bighead carp were monitored over a 6-hr period across each of three raceway treatment level types (functional barrier raceway, non-functional barrier raceway and control raceway). Response variables included enumerating the number of fish above and below each barrier treatment level at 15-minute intervals. In addition, over each 6 hr observation period, the number of attempts to cross a given functional barrier array were continuously recorded as either a successful barrier "repel" or "pass–through". A total of 3219 attempts were made by bighead carp to cross the Sound Projection Array (SPA) driven Bio-Acoustic Fish Fence (BAFF). Of those attempts, 57% were successful repels. In contrast, only 87 attempts were made by bighead carp to cross the Sound Projection Array driven BioAcoustic Fish Fence (SPA driven BAFF) integrated with a Graduated Electric Field Barrier (GEFB). Of those attempts, 83% were successful repels. Finally, 59 attempts were made by bighead carp to cross the Graduated Electric Field Barrier (GEFB). Of those attempts, 100% were successful repels. Existing and potential large-scale applications related to these findings will be addressed.

NOTES

Pheromone Signaling in the Round Goby

Lynda D. Corkum *and Barbara Zielinski*
Department of Biological Sciences, University of Windsor, 401 Sunset Avenue, Windsor, ON N9B 3P4 Canada
T: 519-253-3000 F: 519-971-3609 E: corkum@uwindsor.ca

Weiming Li
Department of Fisheries and Wildlife, Michigan State University
13 Natural Recources Building, East Lansing, MI 48824-1222 USA

Alexander P. Scott
The Center for Environment, Fisheries and Aquatic Sciences, Weymouth, Dorset, UK

All stages of the non-indigenous round goby (*Neogobius melanostomus*) feed on eggs of smallmouth bass, lake trout and lake sturgeon. As successful management of the fishery depends on minimizing sources of mortality, we propose to develop a pheromone-based strategy to decrease the predation effects of the round goby on native fishes. The goal of our study is to characterize the structure and function of sex pheromones that guide female round gobies to nests with parental males. We hypothesize that nesting round goby males release a sex pheromone to attract females to the nests. To test this hypothesis and to characterize this pheromone, we first collect and concentrate water into which potential pheromones from round gobies are washed (released). The presence of pheromones in reproductive male conditioned water has been implicated by electro-olfactogram responses recorded from females. Second, the aqueous and non-aqueous phases are separated, fractionated, and the pheromonal activity of fractions is monitored through physiological and behavioural assays. Third, we intend to determine the chemical structure and function of the reproductive pheromone(s). Here, we present results from behavioural bioassays.

We conducted laboratory experiments to determine if reproductive and non-reproductive females responded to odours of conditioned water in which males (reproductive and non-reproductive) and females (reproductive and non-reproductive) had been held for 4 hours. In these experiments, females were added to a 20 L tank with 18°C aerated dechlorinated water. A shelter was provided at one end of the tank for the fish and odour (control water or conditioned water) was added at the opposite end of the tank. There is a trend for reproductive females to respond to conditioned water odour from reproductive males ($P=0.052$), but not to that from non-reproductive males or from females. Non-reproductive females are attracted to conditioned water odour from reproductive females ($P=0.006$), but not to odours from non-reproductive females or males. Overall, we demonstrated that females of different maturation stages respond by directed movement towards odours in water conditioned by reproductive males and females. Ultimately, we plan to use pheromone traps to temporarily remove round gobies from the spawning grounds of other fishes so that the recruitment of native fishes will be enhanced.

NOTES

The North America Brown Tree Snake Control Team: Keeping Brown Tree Snakes from Becoming Established In North America

Scott E. Henke *and Marc A. Hall*
Caesar Kleberg Wildlife Research Institute, Texas A&M University – Kingsville, Kingsville, TX 78363 USA
T: 361-593-3689 F: 361-593-3924 E: scott.henke@tamuk.edu

Robert Pitman
United States Fish and Wildlife Service, PO Box 1306, Albuquerque, NM 87103-1306 USA

Brown tree snakes (*Boiga irregularis*) are mildly-venomous, rear-fanged snakes that are native to eastern Indonesia, northern Australia, New Guinea, and the Solomon Islands. It was accidently introduced into Guam in the late 1940s and with a lack of natural predators and a prey population that evolved in the absence of a predator, the snake firmly established itself on the 549 km^2 island. Today the population of brown tree snakes on Guam is estimated to be as high as 5800 snakes/km^2. Due to this large population, brown tree snakes have caused major ecological (eg. elimination of forest dwelling avifauna and the Mariana fruit bat), economic (e.g., loss of electrical power), and human health (e.g., bites) problems. Guam's unique status as a deep-water shipping port and as a major US military and civilian air traffic hub results in large quantities of cargo and numbers of people regularly transitting the area. Brown tree snakes have been intercepted as stowaways on planes, boats, and in cargo from Guam. For example, in 1993 a brown tree snake exited a military crate shipped from Guam to Corpus Christi, Texas. Because brown tree snakes pose a serious threat to the United States, the North America Brown Tree Snake Control Team (NABTSCT) was formed. The NABTSCT is composed of multiple state, federal, and private organizations with the sole mission of keeping brown tree snakes from invading North America. The NABTSCT plans to achieve its mission via education and through rapid response of potential sightings of brown tree snakes. Education initiative via our website (www.NABTSCT.org) contains information concerning snake biology, potential pathways for snakes to enter into North America, and photographs to aid in snake identification. Rapid Response initiative uses a toll-free hotline (1-877-STOPANS) to monitor potential sightings and dispatch a response team to capture brown tree snakes. The success of the NABTSCT is imperative to maintain the integrity of local ecosystems in North America.

NOTES

Hydrellia pakistanae and *H. balciunasi* – Insect Biological Control Agents of Hydrilla: Boon or Bust?

Michael J. Grodowitz
US Army Engineer Research and Development Center, Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180 USA
T: 601-634-2972 F: 601-634-2398 E: grodowm@wes.army.mil

Of the four insect species released for the management of hydrilla only the two leaf-mining flies, *Hydrellia pakistanae* and *H. balciunasi* have become established. While the flies have exhibited impressive range extensions since their first release in 1987, populations at most sites have remained below what is considered damaging. Recently, modest to large increases in fly populations followed by hydrilla declines have been observed at several sites including Lake Seminole, FL, Coleto Creek Reservoir, TX, and Sheldon Reservoir, TX. Unfortunately, only limited information is available on the importance of the leaf-mining flies as management tools for hydrilla. For example, long-term tank experimentation has shown that even modest levels of fly damage can significantly reduce hydrilla biomass (50%) and tuber numbers (25%) apparently by reducing photosynthesis thereby decreasing plant vigor and production. Field studies have also substantiated these findings where lower numbers of tubers (60%) were observed at sites on Lake Seminole impacted by fly feeding. Recent small pond studies have shown similar impacts. While more detailed field evaluations are needed, it appears that these agents have the potential to suppress hydrilla populations over the long term even at low to modest levels. However, a complex of factors can influence their effectiveness including plant nutrition especially protein levels, crowding, and the presence of a capable pupal parasite. Further applied and foundational research is still needed including overseas work to identify additional agents and the implementation of new release programs. Based on field surveys, fly releases increases the likelihood of impact since US release sites have as much as a seven-fold higher fly numbers and associated damage than non-release sites.

NOTES

Development of *Mycoleptodiscus terrestris* as a Bioherbicide for Management of the Submersed Macrophyte, *Hydrilla verticillata*

Judy F. Shearer
US Army Engineer Research and Development Center, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199 USA
T: 601-634-2516 F: 601-634-2398 E: shearej@wes.army.mil

Mark A. Jackson
USDA-ARS-NCAUR, Crop Bioprotection Research Unit, 1815 N. University Street, Peoria, IL 61604 USA

Mark A. Heilman
SePRO Corporation, 11550 North Meridian Street, Carmel, IN 46032-4565 USA

The indigenous fungal pathogen *Mycoleptodiscus terrestris* (Mt) has shown significant potential for use as a bioherbicide for management of the invasive aquatic *macrophyte Hydrilla verticillata*. Liquid culture fermentation methods have been developed that yield stable, effective bioherbicidal propagules of Mt. Under appropriate nutritional conditions, aerated Mt cultures produce high concentrations of vegetative biomass that differentiates to form compact hyphal aggregates that we have termed microsclerotia.

The microsclerotia germinate both vegetatively and sporogenically yielding by day 4 approximately 1.8 x 10^6 spores/g dried formulation. By day 12 spore counts had increased 10 fold. Efficacy is also greatly improved over previous methods that used a V-8 medium. When applied at equal rates to hydrilla grown in 55 L aquaria, inoculum from newly developed fermentation methods reduced above ground biomass greater than 95% compared to untreated controls whereas the V-8 based medium reduced biomass less than 40%.

NOTES

Use of *Euhrychiopsis lecontei* as a Biocontrol Agent for Eurasian Watermilfoil: The Response of the Native Macrophyte Community to Introduction of the Milfoil Weevil in the Swartswood Lakes, NJ

Martin Hilovsky
EnviroScience, Inc., 3781 Darrow Rd., Stow, OH 44224 USA
T: 330-688-0111 F: 330-940-4304E: mhilovsky@enviroscienceinc.com

Field and laboratory experiments have demonstrated the potential of a native aquatic weevil, *Euhrychiopsis lecontei*, to be used as a biological control agent for the exotic and invasive aquatic weed, Eurasian watermilfoil (*Myriophyllum spicatum*). Eurasian watermilfoil interferes with recreational activities, contributes to declining water quality and outcompetes native plants in lakes and reservoirs throughout North America. The weevil *E. lecontei* is widely distributed across much of the northern U.S. and Canada. Feeding and fecundity studies have demonstrated that this insect is a milfoil specialist and strongly prefers *M. spicatum* to the native species with which it has presumably coevolved. Over the past five years, more than 60 lakes in 9 states have been successfully stocked with *E. lecontei*, resulting in well-documented declines in Eurasian watermilfoil in most lakes studied. This project examines the response of the native macrophyte community in the Swartswood Lakes, located in western New Jersey, to the introduction of milfoil weevils in 1999 and 2000. Preliminary results indicate that species composition in beds once dominated by Eurasian watermilfoil can change dramatically over a short period of time. Results from the 2000 and 2001 field seasons will be presented which indicate that native macrophytes in the Swartswood Lakes have rebounded and recolonized large areas once dominated by milfoil. Several additional case studies of several successful stockings, and at least one unsuccessful stocking, will also be presented.

NOTES

Two Pioneering Technologies for Aquatic Vegetation Management: Quantification, Application, and Relevant Examples

Douglas R. Henderson
ReMetrix LLC, 11550 N. Meridian, Suite 600, Carmel, IN 46032 USA
T: 317-580-8035 F: 317-580-8290 E: doug@remetrix.com

Technological developments in the past few years have initiated a new era of stewardship, monitoring, and precision management techniques for invasive aquatic vegetation. Two unique technologies impacting large lake management are whole-lake biovolume/biocover mapping, and precision herbicide applications. Whole-lake biovolume/biocover mapping quantifies the extent of vegetation in a lake, providing more effective management planning and long-term monitoring. Biovolume/biocover mapping can also provide an "early warning system" for aquatic managers, since the system can detect and quantify extensive submersed vegetation communities not yet visible at the surface. The mapping is accomplished using advanced hydroacoustics linked to GPS. Software built upon a patented algorithm is used to process the hydroacoustic data for vegetation, and the results are incorporated into a Geographic Information System (GIS) for analysis. The most dramatic results are obtained through multi-year studies using this technology, but even in single-year studies, the management advantage gained is significant.

Precision herbicide application involves the use of customized equipment to carefully tailor the application of aquatic herbicides at varying rates throughout a lake, based upon detailed morphology, vegetation, sediment, and related data. Each of these factors can greatly impact the efficacy of herbicide treatments, and can thereby be accounted for in the equipment to achieve maximum efficacy. Lake characteristics are programmed into the equipment, and the equipment then automatically adjusts the application rate as the treatment progresses in each portion of the lake. The equipment also records the "as-applied" information for later analysis, verification, and record keeping.

This presentation will discuss the basics of the above technologies, and will also provide examples of ReMetrix's pioneering use of these technologies in large water bodies. Overall, these two technologies fold into a broader, more holistic approach for scientific aquatic vegetation management programs. This holistic approach also includes the use of water volume mapping, remote sensing, vegetation surveys, plant bioassays, and sediment characterization. Combined, these technologies provide a data backbone leading to more management value per dollar and improved public communication of strategies and results. Increasing pressures for budgetary and environmental accountability make the incorporation of these technologies tremendously relevant for large lake and coastal vegetation mangers.

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Michigan's Aquatic Nuisance Species Prevention Day

Roger Eberhardt *and Emily Finnell*
Office of the Great Lakes, Michigan Department of Environmental Quality, PO Box 30473, Lansing, MI 48909 USA
T: 517-335-4227 F: 517-335-4053 E: eberharr@michigan.gov

Michigan designated October 2, 2002, as Aquatic Nuisance Species Prevention Day for the state legislature. The purpose of the day was to release Michigan's updated state management plan for aquatic nuisance species to the legislature and raise their awareness of the issue. The Michigan House and Senate each passed a proclamation designating the day. The event was held at the state capitol. Displays were provided by key organizations and agencies, including Michigan Lake and Stream Association, US Fish and Wildlife Service, Office of the Great Lakes of the Department of Environmental Quality, Great Lakes Environmental Research Laboratory, Great Lakes Fishery Commission, Cooperative Institute for Limnology and Ecosystems Research, Great Lakes Science Center, Michigan Sea Grant, and Michigan Department of Agriculture. Among the displays were a number of examples of aquatic nuisance species, including a frozen bighead carp, as well as live sea lampreys, zebra mussels, round gobies, and purple loosestrife. Legislators were able to interact with agency and organization personnel. Presentations by the director of the Office of the Great Lakes, the director of the Department of Environmental Quality, and the Michigan senate majority leader were made in the capitol rotunda during the lunch provided free to all attendees. The presentations focused on the role of the legislature in implementing the updated state management plan. All Michigan legislators were presented the updated plan along with extensive packets of information on aquatic nuisance species. Press releases, post card mailings, Michigan public radio stories, and op-ed pieces in Michigan newspapers publicized the day. The event proved to be an excellent tool for raising awareness about aquatic nuisance species in the Michigan legislature and for introducing legislators to agencies and organizations involved with prevention and control efforts.

NOTES

Education and Outreach on Aquatic Invasive Species in Oregon: Developing a Strategy and Implementation Plan

Diane Kightlinger *and Mark Sytsma*
Center for Lakes and Reservoirs, Portland State University, Portland, OR 97207-0751 USA
T: 503-725-3833 E: Sytsmam@pdx.edu

Paul Heimowitz
Oregon State University Extension Sea Grant, 200 Warner-Milne Road, Oregon City, OR 97045 USA
E: Paul.heimowitz@orst.edu T: 503-655-8636

Invasive species pose an enormous threat to the ecosystems, economy, and health of humans, animals, and plants in Oregon. Although methods exist to control some invasive species, the Oregon Invasive Species Council (OISC) is working to prevent the worst invaders from becoming established in the first place. Unfortunately many people remain unaware that invasive species cause serious problems and that human actions can enable their introduction and spread. Building public awareness and promoting appropriate behavior is therefore an important line of defense in control and prevention of invasive species. A wide range of agencies and organizations in Oregon already engage in invasive species education and outreach. To use limited resources most effectively and achieve the greatest benefits, however, the OISC is coordinating efforts among stakeholders and establishing overarching themes that emphasize the similar concepts that link all invasive species. Our first step is to inventory and assess existing activities and materials to determine where gaps lie in invasive species education and outreach. Next, we will review other public awareness campaigns on environmental issues to identify best practices for informing and educating specific audiences. With that information, we will develop a generic template that outlines the steps necessary to develop an education and outreach plan for any invasive species in Oregon, then proof that template by following it to produce a strategy and implementation plan for education and outreach on aquatic invasive species. The strategy will set forth goals and objectives, list associated activities and products, identify target audiences, develop key messages, and establish effective distribution channels. The implementation plan will specify the responsible agencies and organizations, partners, cost, and schedule. The success of the education and outreach plan for AIS will depend also on obtaining adequate funding and on establishing a credible monitoring and evaluation process. Ultimately we expect that the generic template, strategy and implementation plan, and lessons we learn while pursuing this process will be applicable to other invasive species education and outreach efforts in North America.

NOTES

Interpreting Trends in Media Coverage of Invasive Species

Alysia R. Kravitz *and Richard Campanella*
Center for Bioenvironmental Research at Tulane and Xavier Universities
202 Alcee Fortier Hall, Tulane University, New Orleans, LA 70118 USA
T: 504-862-8441 F: 504-862-8455 E: akravitz@tulane.edu

For the past decade, journalistic attention to invasive species issues has been increasing in major newspapers. Two possible factors explaining this trend include the increased awareness of environmental issues starting in the late 1980s, and a number of high-profile species introductions (zebra mussels, Medfly, snakehead). The depiction of invasive species in these national and international newspaper articles allows researchers to understand how the invasive species issue is being presented to and perceived by the public. This study 1) analyzes trends in invasive species terminology used in newspaper articles; 2) investigates which species have garnered the most media attention; and 3) tests for statistically significant differences among the levels of media attention toward selected species vis-à-vis their relative ecological and economic threats. We will also offer possible reasons why some species are more popular with the press than others. The overall objective of this study is to understand how the public perceives the invasive species problem as it is depicted in the media.

Trends in invasive species terminology are significant because a lack of consensus on how to refer to this ecological threat has impaired efforts to address the problem. Keyword searches of Lexus-Nexus newspaper databases (dating as far back as 1974) were conducted for eight common terms: "invasive species," "exotic species," "alien species," "foreign species," "nonindigenous species," "nonnative species" and "non-native species," "introduced species," and "nuisance species." Since the early 1990s, use of "invasive species" has steadily increased while "exotic species" has significantly declined. "Alien species" remained fairly popular but at stable levels, while "nonindigenous species" and "nuisance species" were consistently unpopular. Use of "introduced species" has increased slightly over the past decade, but remains somewhat less common than "invasive species" in newspaper articles.

To understand which species have garnered the most media attention, Lexus-Nexus searches were also conducted for zebra mussel, Medfly, hydrilla, giant salvinia, nutria, snakehead, and water hyacinth. These species were selected because they range from widely established and highly problematic (such as zebra mussels) to locally or regionally established and a relatively minor threat (such as the snakehead). Analysis of these species-specific data, as well as their geographical patterns, is ongoing.

The summer of 2002 was dubbed "Summer of the Snakehead" for the publicity generated by national media outlets—a publicity that was arguably disproportionate to the size of its threat. The third phase of this study will test whether the media coverage of the snakehead event was statistically significantly greater than other recently introduced species that may pose a greater ecological and economic threat.

These findings may help researchers and managers to agree upon on terminology and strengthen their message when explaining the invasive species problem to the press and to the public.

NOTES

Use of a Web Site for Coordination of a Collaborative Regional Response to Control of *Salvinia molesta*

C. King and ***Kevin Fitzsimmons***
University of Arizona, Environmental Research Laboratory, 2601 E Airport Drive, Tucson, AZ 85706 USA

Robert Pitman
US Fish and Wildlife Service, PO Box 1306, Albuquerque, NM 87109 USA

A Web site (www.lcrsalvinia.org) has been created to coordinate efforts of multiple agencies in regional response to an infestation of *Salvinia molesta* on the lower Colorado River. *S. molesta* was discovered in 1999 in a drainage canal from the Palo Verde Irrigation District in eastern California. Drainage from the irrigation district quickly spread salvinia to the Colorado River, where it entered waters controlled by Arizona, California, and Mexico. Efforts to eradicate or control the weed involved stakeholders from state, regional, and federal agencies from both the US and Mexico. Involving such a variety of agencies in addressing this problem raised a number of complexities in funding, jurisdictional control, collaborative planning, and coordinating physical treatment on the river. In order to facilitate coordination between agencies a website was created to improve communication, dissemination of information, provide a central repository, and information awareness among the general public. Sections of the website include maps, surveys, results of treatment studies, communication links for team members, updated action plans, photo-documentation, archived meeting minutes, and a bulletin board of upcoming and important events. This format may be used as a model for other agencies coordinating collaborative efforts, documenting accomplishments in control efforts, and improving avenues of communication.

NOTES

Inland Seas Education Association's Invasive Species Education Project

Colleen Masterson
Inland Seas Education Association, PO Box 218, Suttons Bay, MI 49682 USA
T: 231-271-3077 F: 231-271-3088 E: CMasterson@GreatLakesEducation.org

Inland Seas Education Association (ISEA) completed its first Invasive Species Education Project in 2002. This project was funded by the US Environmental Protection Agency and included the development of the 1st Annual Invasive Species Field Course, the establishment of an Invasive Species Monitoring Program and the completion of an invasive species section of the ISEA website.

ISEA's 1st Annual Invasive Species Field Course was designed to teach educators, regulators, environmentalists and citizens in the Great Lakes Region about the nature of invasive species. The 3-day course in Traverse City, Michigan, provided a unique combination of hands-on field sampling and professional seminars for twenty participants and eleven faculty members from Michigan, Wisconsin, Illinois and Ontario.

Participants were exposed to current research efforts related to invasive species in the Great Lakes, initiatives to help reduce the introduction and spread of invasives, and ways to incorporate invasive species concepts into classroom teaching. Field work aboard the schooner Inland Seas in Grand Traverse Bay gave participants the opportunity to learn and practice sampling techniques, to develop invasive species identification skills and to gain experience in designing and completing research projects.

The Invasive Species Field Course provided an exceptional forum for course participants to interact with scientists, regulators, mariners and educators. Participants left the course with a new sense of stewardship toward the Great Lakes and a greater awareness of the impacts of invasive species. They also left the course well prepared to teach their students, volunteers and colleagues about invasive species.

As part of ISEA's new Invasive Species Monitoring Program, invasive species of fish, zooplankton and benthic invertebrates were studied at several Lake Michigan sites from May through October, 2002. Data were collected by students (grades 4–12), families, volunteers and ISEA staff as part of ISEA's educational programs.

Invasive species of fish collected in 2002 included alewife (*Alosa pseudoharengus*), common carp (*Cyprinus carpio*), round goby (*Neogobius melanostomus*), rainbow smelt (*Osmerus mordax*) and 3-spine stickleback (*Gasterosteus aculeatus*). Invasive species of zooplankton collected included the spiny water flea (*Bythotrephes cederstroemi*) and the veliger stage of the zebra mussel (*Dreissena polymorpha*). Invasive benthic invertebrates observed were the adult zebra mussel and rusty crayfish (*Orconectes rusticus*).

All science data collected as part of the 2002 Invasive Species Monitoring Program were compiled and are summarized in a final report, available on the ISEA website. Fish, zooplankton, benthic invertebrates and water chemistry data were compared among sampling sites and relationships between the presence or abundance of invasive species and water quality parameters were explored. Seasonal trends were also investigated.

A new section of the ISEA website has been devoted to the topic of invasive species (www.GreatLakesEducation.org/invasivespecies), including information for the public on the Invasive Species Field Course and the Invasive Species Monitoring Program. This site also provides access to the ISEA Science Database, links to other Great Lakes invasive species websites and educational resources for teachers.

Funding from the Kellogg Foundation will support ISEA's 2003 Invasive Species Education Project. In addition to the 2nd Annual Invasive Species Field Course, Invasive Species Monitoring Program and continued website development, this project will include a new 2-day Invasive Species Field Course for teens and an invasive species exhibit in the new Inland Seas Education Center.

Invasive Species Information Management in the Northeast: Laying the Foundation for an International Marine Monitoring Network

Jay Baker
Massachusetts Office of Coastal Zone Management, 251 Causeway St. suite 900, Boston, MA 02114-1219 USA
T: 617-626-1204 F: 617-626-1240 E: jason.baker@state.ma.us

Increasing threats from marine biological invasions in the Northeastern US and Atlantic Canada have led scientists and natural resource managers to intensify marine invasive species monitoring efforts. These short and long term biological monitoring programs provide information on species distributions, dispersal rates and mechanisms, and impacts, contributing to the body of knowledge essential for the effective management of marine invaders in the region. However, these data sets currently reside in a variety of locations and formats, resulting in an incomplete understanding of regional marine invasive species occurrences.

In response to the need for a collective approach to data management, the Northeast Regional Aquatic Nuisance Species Panel (the Panel) and the Massachusetts Office of Coastal Zone Management (CZM) have begun developing a Marine Invasive Species Database for the Northeast Region (MarineID). MarineID will serve as a central repository and clearinghouse for marine invasive species occurrence data, allowing scientists and managers to contribute data online, download relevant information, and visualize changes in species distributions through time.

CZM and the Panel will achieve project goals through an international partnership with the Canadian based Marine Invertebrate Diversity Initiative (MIDI). MarineID will capitalize on a proven web enabled data management foundation laid by MIDI while expanding its online mapping, visualization, and query capabilities. This partnership will also provide access to an existing network of U.S. and Canadian researchers currently collecting biological data in the Northwest Atlantic.

The project proponents are collectively developing the MarineID structure through evaluation of existing invasive species data sets and other biological data models. The resulting minimum set of fields and data reporting requirements will serve as the foundation for a regional monitoring protocol. Once developed, the project team will convene a series of training workshops for state and federal agency representatives, citizens, and researchers with the goals of building a marine invasive species monitoring network for the Northwest Atlantic.

Completion of a fully functioning MarineID system is scheduled for the fall of 2003 and training will begin shortly thereafter. Identification of potential monitoring network participants is ongoing.

NOTES

Combining Allometric Parameters of Biological Processes With Recent Progress in Invasion Theory: Implications for Ballast Water Standards

John M. Drake *and David M. Lodge*
Department of Biological Sciences, University of Notre Dame, PO Box 369, Notre Dame, IN 46556 USA
T: 219-631-4153 F: 219-631-7413 E: drake.4@nd.edu

Mark Lewis
Department of Mathematical and Statistical Sciences, University of Alberta, 632 Central Academic Building
Edmonton, AB T6G 2G1 Canada

Introductions of non-indigenous species in ballast water are one of the greatest threats to freshwater and marine ecosystems worldwide. Therefore, new approaches to reducing the release of organisms from ballast water are under consideration nationally and internationally. In the US, new interim and final standards for allowable releases of organisms will likely be established over the next few years. However, such efforts have been retarded by the apparent absence of relevant information about the identity and numbers of organisms in ballast tanks, and the lack of relevant ecological theory.

Here, we provide a novel approach to estimating the risk of establishment of organisms based on membership of the organism in broad taxonomic categories (primarily at the class level and above) and on the volume of ballast water released. Our two-step approach is as follows. First, we determine approximate body size and hence the rate of potential population growth from a well-known allometric relationship. Next, we estimate realized population increase and spread from recently developed theory that incorporates the important effect of diffusion of organisms in the aqueous habitat and the Allee effect (i.e., the density dependence of population growth rate that includes declining growth rate at low densities due to inability to find mates in sexually reproducing species). Risk, according to this framework, is based on incomplete information. Hence, estimates of invasion risk rely on determining the uncertainty associated with each step. This approach is potentially applicable in the short term because its information requirements are minimal

Our approach is applicable to a wide variety of taxonomic groups including most amphipods, arthropods, barnacles, cnidaria, ctenophores, copepods, decapods, echinoderms, fishes, leeches, molluscs, ostracods, and polychaete worms. Thus, with our approach it is possible to make generalized estimates of invasion risk at the scale that is necessary for the development of practical policy to reduce ballast-mediated invasions. To demonstrate, we studied invasion risk for some mollusks, crustaceans, fishes, and ctenophores. As an example, our results indicate that for a risk threshold of 0.01 (meaning that for every introduced species a probability of establishment no greater than 1% is acceptable) independent releases of untreated ballast water should be no greater than 30,000 metric tonnes. (Multiple releases of the same species in a short period of time can cause "rescue effects" and are therefore not independent.)

Merits of our technique include that it provides rational methods for handling uncertainty and can be easily modified to incorporate additional biological or hydrological information, such as the efficacy of treatment systems (filtration, toxins, etc.), local information about organism spread, and information about the distribution of ships and organisms released in ballast water. Additionally, we suggest that this approach is a suitable basis for deriving ballast water standards because it meets three criteria that we think are critical for any standards: 1) The approach is consistent with current theory in invasion biology, which indicates that the combination of spatial spread and population growth dynamics create a nonlinear relationship between probability of establishment and propagule pressure; 2) The approach considers known differences among taxa, so that standards are not unreasonably set to the "lowest common denominator"; and 3) The approach is applicable to a broad range of species. Any standard that fails to meet the first criterion is not amenable to scientific evaluation. A standard that fails to meet the second criterion would prohibitively expensive. A standard that fails to meet the third criterion would be unenforceable. Perhaps most importantly, our method does not make any assumptions about the level of risk that is socially acceptable, but rather allows for acceptable risk levels to be specified during the decision-making process. Thus, with information that is currently available or likely to be available in the near future, this approach provides reasonable estimates for the risk that a ballast release will cause the establishment of unwanted species.

Risk Assessment for Prediction of Invertebrate Invaders in the Laurentian Great Lakes

***Igor A. Grigorovich**, Robert I. Colautti and Hugh J. MacIsaac*
Great Lakes Institute for Environmental Research, University of Windsor, Windsor, ONN9B 3P4 Canada
T: 519-253-3000 x 3749 F: 519-971-3616 E: igrigorovich@hotmail.com

Since completion of the St. Lawrence Seaway in 1959, the Laurentian Great Lakes have been invaded and dramatically altered by more than 43 animal invaders. Nearly 67% of these were attributed to ballast water transport by commercial vessels. We developed a qualitative risk-assessment framework to predict potential invertebrate invaders in the Great Lakes. Risk level was estimated using a sequence of "screens" as follows: 1) strong shipping pathways and vector activities linking high-risk donor regions with the Great Lakes; 2) species' invasiveness; (3) salinity and climate matches between recipient and donor regions; 4) species' ability to interface with ballast water vectors; and 5) species life histories and environmental tolerances enhancing inoculant survival during uptake and transportation in ballast tanks. We first identified the major donor regions contributing to Great Lakes' shipping traffic. Next we assembled a list of aquatic invertebrate species with documented histories of invasiveness in these regions. We determined whether these species are capable of complete their life cycle entirely in the Great Lakes' milieu using water temperature and salinity characteristics of their native habitats (obtained from published and unpublished sources). Next we judged whether species could exploit ballast water transport vectors by examining evidence for their occurrence in the ballast medium based upon ballast tank surveys. For those taxa that are likely to be transported in ballast tanks but not recorded aboard vessels, we required evidence of unintentional secondary spread along invasion corridors. We then assessed which species, at any life stage, are likely to survive the adverse conditions associated with ballast-mediated transfer and estimated their ability to become established. The invasion risk was identified: (i) for vessels declaring "No ballast on board" (NOBOB) status by examining species' capability of producing resistant life stages or tolerance to reduced oxygen content, and (ii) for ballasted ships by examining species' tolerance to salinity ≥17‰. Species that possess life history traits and environmental tolerances amenable to transportation and survival in ballast tanks of either NOBOB or ballasted ships were categorized as posing a high risk for establishment in the Great Lakes. Our risk-assessment model identified 24 high-risk, of which ten species have already invaded the Great Lakes during 1959–1999, encompassing time periods before and after the implementation of U. S. mandatory ballast water exchange (BWE) legislation in 1993. An additional 37 low-risk species, of which five have invaded prior to 1993, show some but not all attributes needed for successful ballast-mediated transfer under the current BWE regulation. List of predicted invaders is provided in the manuscript submitted to the *Canadian Journal of Fisheries and Aquatic Sciences* (e.g., I.A. Grigorovich, R.I. Colautti, E.L. Mills, K. Holeck, and H.J. MacIsaac. 2003. Ballast-mediated animal introductions in the Laurentian Great Lakes: retrospective and prospective analyses. In review). We contend that the Great Lakes remain at risk of new introductions mediated by transoceanic vessels.

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A Null Hypothesis for Invasions

***Robert I. Colautti**, Igor A. Grigorovich and Hugh J. MacIsaac*
Great Lakes Institute for Environmental Research, University of Windsor, 29909 Riverside Drive, Windsor, ON N9B 3P4 Canada
T: 519-253-3000 x 2734 F: 519-971-3616 E: rob_colautti@yahoo.com

Researchers have long sought to explain variation in the relative success of invaders (i.e., 'invasiveness') or the susceptibility of habitats and communities to invasion (i.e., 'invasibility'). Developing such predictive criteria would be of immense benefit to resource managers, and could lead to novel discoveries relevant to ecology and evolution. But despite numerous theoretical attempts to envisage generalizations about successful invaders or susceptible habitats, experimental efforts have unearthed discouraging results. In a review of experimental and statistical tests of 'invasiveness' and 'invasibility' for both terrestrial and aquatic plants and animals, we identify a large number of characteristics, some contradictory, which render broad generalizations difficult. Similar findings have led other authors to suggest that a *priori* predictions are likely system and taxon-specific, or altogether unattainable. In addition, we find that attempts to collate invasion paradigms are confused by a lack of consensus on operational terms and concepts. Even the most basic of invasion terms, such as 'invasive', 'nuisance' and 'naturalized', carry varied meanings among studies, and are often not defined explicitly. Finally, we examine the role of propagule pressure (i.e., variation in introduction 'effort') and find strong correlations with reported invasion patterns, strongly implicating propagule pressure as a significant determinant of invasion success. Given the myriad potential factors affecting invasion patterns, a lack of consensus on important concepts, and the confounding potential of propagule pressure, we suggest that a new perspective is needed. Using propagule pressure as the null hypothesis, we present a conceptual framework for invasions that also serves as a compromise for terms with multiple definitions. Our hope is that this model may lessen confusion, and serve as a framework to focus future research efforts.

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Technology Policy Implications for Ballast Water Introductions of Non-indigenous Species

Nicole Cass
University of Delaware, College of Marine Studies, 1043 Christina Mill Drive, Newark, DE 19711 USA
T: 302-831-8086 F: 302-831-6838 E: ncass@udel.edu

The problem of non-indigenous species introductions only escalates, as the world becomes a global economy. Increased trade between different locations provides new vectors of introduction for many non-indigenous species. The most common method of introduction has been identified as ballast water from ships. The scientific community is currently trying to evaluate the economic, ecological, and human impacts of these introductions, but it is increasingly important that policy analysts become involved in the research. There is currently not a model that can determine the likelihood that an introduced species will become invasive. It therefore is necessary to evaluate the potential of reducing the risk factors that lead to introductions. Policy makers at the national and international level are currently struggling to formulate and implement policies that will effectively reduce the risk of introductions to coastal waters. The proposed policies advocate a global standard that may not adequately protect the environment and may impose unnecessary restrictions or financial burdens on the shipping industry.

The risk reduction model developed through this research evaluates both the likelihood of invasions from oceanic voyages as well as coastwise shipping introductions. The model characterizes three elements: 1) the port of origin environment (e.g., salinity, temperature); 2) the voyage factors (e.g., treatment method, length of voyage, volume of ballast, and ballasting events); and 3) the port of destination environment to determine the risk reduction potential of technology policy combinations. This work evaluates the risk of species being introduced and then extrapolates to produce an estimate of invasion risk.

The model will be applied to a variety of ports in the United States, representative of geographic location, vessel type, cargo volume, and ecological conditions. The model is intended to evaluate the available policy and technology solutions to determine the most effective combination to reduce the risk of introduced species to individual port environments. The model will illustrate the dominant factors of introduction and the areas of greatest concern. Information from the model will enable policy makers to implement policies that address specific factors and trade routes, instead of the broad issue of invasions.

The risk reduction model can be applied to any port to determine which policy and technology combination will most effectively combat the risk of introduction of invasive species. The model developed by this research will inform the policy making process by evaluating the factors that are controllable by regulations, technology and policy requirements. Previous research and models in this area have address the biological conditions necessary for invasion, these cannot be changed by regulations, therefore it is necessary to develop a model that involves the ports and ships, the two areas that can be regulated. This presentation will discuss the development of the model and explain the factors evaluated by the model, and preliminary results from the Port of Houston, Texas.

NOTES

Quantification of Risks of Alien Species Introductions Associated with Alternative Areas for Ballast Water Exchange in the Laurentian Channel of the Gulf of St. Lawrence

Renata Claudi *and Ravi Ravishankar*
RNT Consulting Inc., RR 2 Picton, ON K0K 2T0 Canada
T: 613-476-7994 F: 613-476-7994 E: rnt@idirect.com

Canada has one of the longest navigable coastlines in the world, bordering the Atlantic, Arctic and Pacific Oceans, as well as the Great Lakes. Shipping is important to the Canadian national and international trade. Our coastal waters receive yearly over 52 million tonnes of ballast water from foreign ports around the world (Gauthier & Steel 1966). Millions of tonnes of ballast water are discharged into the Estuary and Gulf of St. Lawrence each year. Ballast water has been identified as one of the pathways by which alien aquatic species are introduced outside of their normal range. Under the current Canadian voluntary guidelines, all ships entering Canadian Waters are expected to exchange ballast water outside of the Exclusive Economic Zone (EEZ). The 2001, Transport Canada survey has shown that 77% of all ships entering the Gulf of St. Lawrence have exchanged ballast water in mid-ocean. Of the remainder, 8.5 % are ships, which declared that as they are coming up the North American coastline they are exempt from the need to exchange. Additional 13% do not have a clear reason for not exchanging and may in fact also be part of the coastal trade. Less then 1% of all ships surveyed declared safety as a reason for not doing the exchange.

The current guidelines make provisions for ballast water exchange in "back-up areas", if exchange is not feasible offshore for safety reasons. Incoming foreign ships may exchange their ballast waters within the Gulf of St. Lawrence, in the Laurentian Channel southeast of Anticosti Island, where depth exceeds 300 m. The magnitude of the risk such ballast water exchanges pose, compared to risk from ballast water discharge in other areas of the Gulf of St. Lawrence was evaluated using a Probabilistic Risk assessment model. The risk was measure in terms of quantity of alien species introduced into various parts of the Gulf, including the Laurentian Channel, giving current shipping patterns and practices.

This presentation will discuss the results of the study and propose that the model employed could be used to simulate a number of "what if" scenarios. Such approach could help test the impacts of any new shipping guideline or regulations on the risk of alien introduction into the Gulf of St. Lawrence.

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Invasion Kinetics of Spiny Waterflea Dispersal in Ontario

Jim Muirhead *and Hugh J. MacIsaac*
Great Lakes Institute for Environmental Research, University of Windsor, 29909 Riverside Drive, Windsor, ON N9B 3P4 Canada
T: 519-253-4232 x 2734 F: 519-971-3609 E: muirhe1@uwindsor.ca

Range expansion by the spiny waterflea (*Bythotrephes longimanus*) to inland Ontario lakes is driven by a combination of local diffusion and rare, long-distance dispersal events, all mediated by human activities. In such a stratified diffusion process, once a lake has become invaded, it can serve as an additional source, or "hub" for future invasions. We surveyed boaters about trailering movements and other recreational activities to model the relative vector traffic from invaded lakes to other invaded and non-invaded lakes. We ran Monte Carlo simulations on the cumulative number of invaded and non-invaded destination lakes identified in the surveys as a function of the number of surveys conducted for Lake Huron and four important invaded inland lakes: Simcoe, Muskoka, Panache and Kashagawigamog. The saturation curve for the cumulative number of new lakes identified vs. the number surveyed is consistent with a Michaelis-Menton enzyme kinetics model. A comparison of half-saturation rates between invaded and non-invaded destination lakes provides information on whether a particular source lake will continue to develop as a hub for future invasions, or if the number of invaded destination lakes has become saturated. Our analysis indicates that the spiny waterflea from Lake Muskoka has invaded most of the lakes it can invade (i.e., Lake Muskoka has served as a hub) while Lake Simcoe is likely to become a new hub. Invaded lakes which have the potential to develop into major hubs to non-invaded lakes could then be targeted for education efforts to reduce the rate of spread.

NOTES

A Risk Assessment Protocol for Non-Native Freshwater Fishes

Gordon H. Copp
CEFAS Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk NR33 OHT England
T: 44-1502-527751 F: 44-1502-513865 E: g.h.copp@cefas.co.uk

Rachel Garthwaite
CEFAS Lowestoft Laboratory and Department of Conservation, P.O. Box 10-420, 65 Victoria Street, Wellington, New Zealand

Rodolphe E. Gozlan
Centre for Ecology and Hydrology – Dorset, Winfrith Technology Centre, Winfrith Newburgh, Dorchester, Dorset DT28ZD, UK

No binding international instruments are in place to assess the introduction of non-native species to freshwater ecosystems. However, the Convention on Biological Diversity (CBD) requires parties, as is possible and appropriate, to prevent the introduction of, and to control or eradicate, alien species that threaten native ecosystems, habitats or species, and recommends the use of risk assessment to justify actions taken against such threats. International trade and transport are major pathways for the spread of non-native species. Where sufficient risk can be scientifically demonstrated, countries may impose national measures to prevent their introduction. Guidelines for pest risk assessment, and the development of national measures to protect plant life and health, have been issued by the European Plant Protection Organisation (EPPO) under the International Plant Pest Convention (IPPC), a standard-setting body recognized under the World Trade Organisation 1995 Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement). Whilst not directly relevant to freshwater fish pests, these standards provide a useful guide for the development of independent risk assessment frameworks for other taxonomic groups. Using the EPPO protocol as a model, we present a conceptual framework for a Pest Fish Risk Assessment (PFRA). This semi-quantitative protocol, developed specifically for the UK but potentially applicable elsewhere, is designed to provide a comprehensive, transparent, assessment of the overall risk posed by a non-native freshwater fish species, including pathway analysis, so as to inform policy decisions relating to pre-border, border and post-border procedures and related legislation.

NOTES

Determining the Potential for Fish Predation to Limit Zebra Mussels *Dreissena polymorpha* Across Latitudinal Gradients Using Bioenergetic Models

Michael A. Eggleton
3105 Ridgecrest Court, Apt 821, Norman OK 73072 USA

L. Esteban Miranda
USGS Biological Resources Division, Mississippi Cooperative Fish and Wildlife Research Unit, Box 9691, Mississippi State, MS 39762 USA

James P. Kirk
US Army Engineer Research and Development Center, Environmental Lab, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199
T: 601-634-3060 F: 601-634-3298 E: Kirkj@wes.army.mil

Bioenergetic modeling provided insight into the potential of fishes to consume zebra mussels *Dreissena polymorpha* over eastern North America (13° latitude x 12° longitude) and suggested fishes in southern latitudes consume up to 100% more food than those in northern systems. Much variation in food consumption was due to differing water temperature regimes. Consumption of zebra mussels was also influenced by the standing crop of different species, and the fish community as a whole. Fish communities followed predictable patterns along both longitudinal and latitudinal gradients. Analyses indicated a tendency for central and southern US systems to contain greater standing crops of fish likely to consume zebra mussels. Lake sturgeon *Acipenser fulvescens* had the greatest potential to consume zebra mussels of all the species evaluated in this study. This study supports the premise that fishes in more southern (including central) US waters have inherently greater potential to impact zebra mussels and provides a partial explanation of why zebra mussel densities of been considerably lower in southern US waters.

NOTES

Predictive Ecological Niche Modeling Using GARP; Carp Invasion in the United States

Kristina McNyset *and Shannon DeVaney*
Natural History Museum, University of Kansas, 1345 Jayhawk Blvd., Lawrence, KS 66045-7561 U.S.A.
T: 785-864-3369 F: 785-832-2852 E: krhode@mail.ukans.edu

Justin Williams
US Geological Survey, Center for Aquatic Resource Studies
7920 NW 71st Street, Gainesville, FL 32653 U.S.A.

An innovative method for predicting species potential distributions in foreign areas was used to predict possible establishment of exotic freshwater fish species in the United States. Ecological niche models of three species of exotic carp (family Cyprinidae) were developed using GARP (the Genetic Algorithm for Rule-set Prediction) with emphasis on the black carp (*Mylopharyngodon piceus*), a freshwater fish native to east Asia. This fish has been imported into the United States for use in aquaculture but is has not yet become established. In addition, the niches of the already established common carp (*Cyprinus carpio*) and grass carp (*Ctenopharyngodon idella*) were modeled and then tested using occurrence points from populations in the US. The three species modeled represent a chronology of carp importation to the United States and associated levels of establishment, spread, and impact in ecosystems. Projection of the black carp niche model onto North America suggests a high invasive impact, most probably in the eastern United States. This predictive modeling method provides valuable new information to decision makers and can be applied in the future to determine the threat of various taxa of exotic species before an invasion occurs.

NOTES

Ecological Niche Modeling, a New Tool for Decision Makers

Daniel A. Kluza *and James K. Andreasen*
US Environmental Protection Agency, Office of Research and Development
1200 Pennsylvania Avenue, Washington, DC 20460-0001 USA
T: 202-564-3293 F: 202-565-0076 E: andreasen.james@epa.gov

A. Townsend Peterson
Department of Ecology and Evolutionary Biology, University of Kansas
Lawrence, KS 66045-7561 USA

Aquatic ecosystems around the world are being transformed and degraded by invasive species plants and animals, including predators, competitors or pathogens, that evolved elsewhere and can consequently invade new habitat and outcompete other species. The impacts of these invasive species can be severe, damaging ecosystems and undermining the local economies they support. The increase in global trade raises the risk of aquatic invasive species introductions to the NAFTA countries of Canada, Mexico and the United States. This presentation discusses a tool for helping managers and decision makers predict where a species might spread following its introduction into a new environment.

A species geographic distribution is the result of complex interactions of historical and ecological factors, and present serious challenges for modeling. We have been working with an ecological niche model that uses the Genetic Algorithm for Rule-set Prediction (GARP, a machine-learning algorithm) to provide an effective solution to predicting where a species might spread following introduction to a new area. Species ecological niches can be modeled, and their potential geographic distributions predicted with high statistical confidence. This tool provides a powerful new procedure for modeling the spread species invasions and developing optimal conservation strategies.

GARP is another tool that can help decision makers and environmental managers make better, and more timely, decisions. This presentation will demonstrate the utility of GARP using data from a variety of species that have been modeled.

NOTES

Does Proximity to Roads Increase the Risk of Non-native Ornamental Fishes Being Introduced to Ponds Situated in Urban Areas?

Gordon H. Copp *and Mark Ives*
CEFAS Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk NR33 OHT England
T: 44-1502-527751 F: 44-1502-513865 E: g.h.copp@cefas.co.uk

Keith Wesley
Bedwell Fisheries Services, 22 Puttocks Lane, Welham Green, Hertfordshire, AL9 7LP, England

We examined the possible role of humans as vectors in the colonisation by non-native fish species of natural and man-made ponds in Epping Forest and the County of Hertfordshire. We included ponds that had been drained of water and voided of fish (or treated with rotenone) on a known date and in which no piscivorous fish had been restocked. We measured the period of time since pond restoration, pond area, distance to nearest residential housing, distance to nearest footpath, and distance to nearest water body or stream. Talling's (1951) 'element of chance' as a natural phenomenon appears to play a minor role, if any, in the colonisation of ponds in urban areas, as we found a significant decrease in both the number of varieties (species and morphs thereof) and the density (fish/10 min. electrofishing) of non-native fishes with increasing distance from the nearest road. And in keeping with ecological theory, the number of varieties of non-natives increases significantly with increasing density of non-natives. The implications for conservation and management are discussed.

NOTES

The Effects of Bass Introductions on Lake Trout Populations in the Haliburton Highlands of Central Ontario

David M. Brown
Ontario Federation of Anglers and Hunters
PO Box 2800, Peterborough, ON K9J 8L5 Canada
T: 705-748-6324 F: 705-748-9577 E: dave_brown@ofah.org

John M. Casselman
Ontario Ministry of Natural Resources, Aquatic Research and Development Section
Glenora Fisheries Station, RR 4, Picton, ON KOK 2T0 Canada

Rock bass (Ambloplites rupestris) and smallmouth bass (Micropterus dolomieu) were introduced (unauthorized) into Macdonald Lake, Ontario, in the mid 1980s, while smallmouth bass were first observed in Clean Lake, Ontario, in the early 1980s and rock bass in the mid 1990s.

To assess the impacts of bass introductions, and subsequent fish community changes, 18-year growth chronologies (1978 - 1996) were constructed for lake trout from both lakes. Growth of older lake trout in Macdonald Lake declined to 22% below average, while growth in Clean Lake remained unchanged. Ultimate size (L infinity) declined 18% in Macdonald Lake lake trout between 1987 and 1996. The body mass of an age 7 female lake trout in Macdonald Lake declined from 556g (TL = 408 mm) to 323 g (TL = 343 mm), a 42% reduction.

Growth was correlated with the biomass of littoral zone prey ($r^2 = 0.71$, $P = 0.004$). Following the introduction of bass, biomass of prey in Macdonald Lake decreased by 95% in quantitative electrofishing surveys. These littoral zone prey were an important component of the lake trout diet in spring and fall, prior to bass introductions and their loss resulted in significant changes in the growth of lake trout.

NOTES

Pike Removal in Lake Davis, California

Ivan Paulson
California Department of Fish & Game
P.O. Box 1858, Portola, CA 96122 USA
T: 530-832-4067 F: 530-832-9706 E: ipaulsen@dfg.ca.gov

Northern Pike (Esox lucius) are a non-native, predatory fish which were illegally introduced into California in the mid to late 1980's. They first appeared in Frenchman Lake, located approximately 30 miles east of Lake Davis, and were successfully eradicated from this lake by the Department of Fish and Game in 1991. Pike appeared in Lake Davis in 1994 and again the Department attempted to eradicate them from Lake Davis in 1997, a project which gained national attention when the local community attempted to prevent the eradication of the pike through the use of piscicides. In 1999, pike reappeared in Lake Davis. With their reappearance, the Department undertook an aggressive program of controlling the pike population and preventing their escapement from Lake Davis until such time as an acceptable method could be determined on how to eradicate the pike from the lake. Our project is one of the highest level priorities with the Director of the Department of Fish and Game.

The immediate danger of having pike in the lake is the threat to the lake's trout fishery. The larger danger of having pike in the lake is their potential for either escaping or being moved to other waters of the state of California, in particular the California Delta system. At threat in the Delta system are the native salmon and steelhead populations, which the State and Federal governments are currently spending hundreds of millions of dollars to enhance. Additionally, they pose a threat to all species of fishes found in the Delta, some of which are Federal or State listed species. The pike's ability to destroy fisheries is painfully evident in southern Alaska where pike were illegally introduced and have destroyed salmon and trout populations.

NOTES

Return to the Sea: Homo Sapiens Help *Osmerus mordax* Invade Hudson Bay

William G. Franzin
Fisheries and Oceans, Central and Arctic Region, Freshwater Institute
501 University Crescent, Winnipeg, MB R3T 2N6 Canada
T: 204-983-5082 F: 204-984-2404 E: franzinw@dfo-mpo.gc.ca

Rainbow smelt have been expanding their North American range in the central part of the continent for nearly 100 years. Since they were introduced successfully into the Great Lakes drainage in about 1912 they have increased their range immensely by colonizing new waters on their own and by intentional and unintentional human introductions to the Mississippi and Hudson Bay watersheds. Rainbow smelt are able to spread downstream in a watershed very quickly. The species spread from Lake Sakakawea, a mainstem Missouri River reservoir in North Dakota to the Gulf of Mexico in about eight years. In the Hudson Bay drainage, they spread from time of detection in the mainstem lakes of the Rainy River, ON and MN in 1989, and upper English River lakes in ON in 1986, all way to the mouth of the Nelson River by 1998. They have now begun spreading in the marine environment of Hudson Bay. In this paper, I report the present range of rainbow smelt along these mainstem colonization routes as well as update the unintentional spread of this species by humans into adjacent waters of the Great Lakes, Mississippi and Hudson Bay watersheds. Given documented and suspected effects of this species, particularly in small lakes, rainbow smelt remains one of the most damaging exotic fish species continuing to spread in North America.

NOTES

Why a 100th Meridian Initiative?

Bob Pitman
US Fish & Wildlife Service, Region 2, PO Box 1306, Room 3118, Albuquerque, NM 87109 USA
T: 505-248-6471 F: 505-248-6845 E: bob_pitman@fws.gov

1996 amendments to the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 required the Western Regional Panel (established in the reauthorization) of the Aquatic Nuisance Species Task Force to recommend an, education, monitoring, prevention, and control program to prevent spread of zebra mussels west of the 100th Meridian. The two goals of the Initiative are 1) prevent spread of zebra mussels and other ANS in the 100th meridian jurisdictions and west; and 2) monitor and control zebra mussels and other ANS if detected in these areas. The 100th Meridian Initiative is a strategic approach to prevent the westward spread of zebra mussels and other aquatic invasive species.

Soon after the zebra mussel invasion in the mid-1980s it was recognized that the only way this invasive species would spread west of the 100th Meridian would be through human assisted pathways. A report by Tyus, Dwyer, and Whitmore in 1993 pointed out the threat from recreational boats being transferred from infested waters to western locations. Boats with zebra mussels attached have been detected in several western states and at California border inspections. Collaboration and stakeholder involvement is essential to effectively combat invasive species. The 100th Meridian partnership is an example of collaboration that covers a wide section of North America in an effort to protect western waters. While there are other pathways to the west, concentrating on boaters and trailered boats could help identify and block other pathways.

Seven components are being addressed to achieve 100th Meridian Initiative goals.

1) **Information and Education:** Inform and educate the public.

2) **Voluntary Boat Inspections and Boater Surveys:** Conduct voluntary boat inspections and boater surveys.

3) **Commercially hauled Boats:** Educate and work with commercial boat haulers and professional fishing tournaments to prevent spread.

4) **Monitoring:** Establish monitoring sites in the west to determine if zebra mussels or ANS are present.

5) **Rapid response:** Contain or eradicate zebra mussels if detected.

6) **Identification and Risk Assessment of Additional Pathways:** Evaluate pathways to the west and develop actions for those with higher risk for westward spread of ANS.

7) **Evaluation:** Regularly review and make adjustments to actions to ensure effectiveness in preventing westward spread.

Actions of the 100th Meridian are updated at http://www.100thMeridian.org

NOTES

Risks to the West – A Western Regional Panel Objective

Erin Williams
US Fish and Wildlife Service , 4001 N. Wilson Way, Stockton, CA 95205-2486
T: 209-946-6400 x 321 F: 209-946-6355 E: Erin_Williams@fws.gov

This abstract was not available at the time of printing.

NOTES

The Aquatic Nuisance Species Program in Utah

Donald L. Archer
Utah Division of Wildlife Resources, PO Box 146301, Salt Lake City, UT 84114-6301 USA
T: 801-538-4817 F: 801-538-4745E: donarcher@utah.gov

Utah's ANS program got a kick-start in April 1998 when staff from the Minnesota and New York National Sea Grant programs conducted an ANS workshop in Salt Lake City. The workshop was instrumental in energizing many of the participants to initiate an ANS program in Utah.

At the conclusion of that workshop, those interested organized what became known as the Utah ANS Action Team composed of about 20 individuals representing about a dozen agencies. They met several times that spring and summer and drafted a mission statement "to prevent or impede the spread of ANS species in Utah".

They established four objectives: Define species of concern, develop an action plan, establish a communications network, and identify funding needs.

At that time there was thought to be three species of concern: zebra mussels, Eurasian, watermilfoil and purple loosestrife, since then an exotic daphnia and the New Zealand mudsnail have been discovered.

The Team identified three Actions Items: Assess level of risks; establish an early warning system for ZM; and develop a number of public education materials and media to alert the public to the problem, illicit their support and heighten their concern

Initially risk assessment involved collecting a season data at L Powell. That assessment demonstrated that the risk was low as there were only 70 boats out of 150 000 that originated from those states having zebra mussel infestations. As a result it was decided that further risk surveys weren't warranted.

The monitoring system has been undertaken primarily by the Division of State Parks as they have facilities on most of the state's major waters and people on site to conduct inspections. We now receive annual inspection reports from 24 state parks, 5 National Recreation Area sites on Lake Powell and 5 sites from the National Recreation Area at Flaming Gorge Reservoir.

The team began developing media in the form of TV and radio pieces, brochures, and articles in the papers and the Wildlife magazine. 50 000 tri-fold brochures were designed and printed for distribution. An abridged version of the brochure was inserted into 75 000 boater and camper license registration forms in 1999.

The Team also developed a sign with the classic stop sign symbol on it to be installed at boat ramps and other access points informing the public of the problem of ANS and enlisting their help in avoiding accidental transfer of ANS. One hundred of those signs have been produced and installed at many of the state's lakes and reservoirs. 500 were produced for the FWS with and are being distributed throughout the Colorado River basin.

The Division of Parks and Recreation are constructing kiosks carrying an ANS message for installation at the major lakes and reservoirs. Fifteen are in place, 15 more are being constructed and 15 more are being planned.

The Team is now moving toward developing ANS management and rapid response plans. Funding is being sought for that effort.

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The 100th Meridian Initiative: Database and Web Site

David Britton
Department of Biology, The University of Texas at Arlington, Box 19498, Arlington, TX 76109 USA
T: 817-272-5577 F:817-272-2855 E: britton@uta.edu

Bob Pitman
US Fish & Wildlife Service, Region 2, PO Box 1306, Room 3118, Albuquerque, NM 87109 USA

Robert McMahon
Department of Biology, The University of Texas at Arlington, Box 19498, Arlington, TX 76109 USA

The 100th Meridian Initiative is a cooperative effort between state, provincial, and federal agencies to prevent westward spread of zebra mussels and other aquatic nuisance species in North America. Since many types of aquatic pests are easily transported between drainage systems by trailered boats, the Initiative informs and educates boaters about aquatic nuisance species while conducting voluntary boat inspections and boater surveys at launch locations. Survey activities, commencing in 1998, included boat trailer license-plate surveys in parking lots and border crossings, and boater interviews designed to assess potential vectors of aquatic nuisance species spread. Data collection has increased exponentially since 1998 and includes information from Texas, Oklahoma, Kansas, South Dakota, Nebraska, North Dakota, Idaho, Montana, Oregon, Wyoming, Nevada, and Manitoba. All data obtained is stored in a centralized database and available online at 100thmeridian.org. Analysis of 100th Meridian Initiative data indicates that a considerable amount of trailered boat traffic crosses state and provincial lines and underscores the necessity of public outreach and education efforts in preventing the spread of aquatic nuisance species.

NOTES

Interjurisdictional Responses to Reduce the Threat of Zebra Mussels and Other Aquatic Nuisance Species (ANS) as a Result of Lewis and Clark Bicentennial

Bill Zook and ***Stephen H. Phillips***
Pacific States Marine Fisheries Commission, 45 SE 82nd Drive, Suite 100, Gladstone, OR 97027 USA
T: 503-650-5400 F: 503-650-5426

The year 2003 marks the beginning of the Bicentennial of the Lewis and Clark expedition. It is expected that thousands of large and small boats, canoes, and other watercraft will be paddled, motored, and trailered along Lewis and Clark's route through the Missouri, Clearwater, and Columbia Basins in commemoration of the expedition. The anticipated mass movement of watercraft from the Midwest to the west of the 100th Meridian represents a significant vector for potential movement of zebra mussels. In response to that threat, the USFWS and Bonneville Power Administration are funding the Pacific State Marine Fisheries Commission for ANS educational and mitigative activities associated with the Bicentennial.

This outreach program directly addresses the concern of western water resource managers that the influx of boaters, coming from all regions of the country for the Lewis and Clark Bicentennial celebration, will increase the risk of transferring zebra mussels or other ANS into the Missouri River Basin and further west. The objective of the outreach program, therefore, is to reduce this risk by employing a variety of targeted educational outreach efforts designed to increase public awareness.

The Program will expose those boaters most likely to participate in Lewis and Clark Bicentennial activities to information on boating equipment inspection and cleaning as a means of preventing the spread of ANS. And, make this information available to boaters in a variety of ways from the time they begin planning a trip to the Missouri River all the way to the boat launch.

Some of the key elements of the program include:

- Providing timely and regularly updated ANS prevention information targeted at Lewis and Clark Bicentennial boaters on the national level through print and electronic media.
- Erecting low-frequency radio signals (Traveler Information Stations [TIS]) at major highways used by boaters to access the Missouri River from the east. Radio messages will advise boaters to clean all boating equipment when coming from zebra mussel states and provide them with the location of the nearest boat cleaning station.
- Developing partnerships with marina, resort and portage operators in the Missouri River Basin between Fort Peck Reservoir and Bellevue, Nebraska. These partnerships will result in the owner/operator providing ANS prevention information in prominent places on site and offering power wash service at a subsidized cost for boaters coming from zebra mussel states.
- Providing ANS and boat cleaning information signs at every boating access on the Missouri River from Bellevue, Nebraska to Fort Peck Reservoir in Montana.
- Coordinating efforts with the 100th Meridian Initiative, a cooperative effort between state, provincial, and federal agencies to prevent the westward spread of zebra mussels and other aquatic nuisance species in North America.

NOTES

Preventing the Invasion of Zebra Mussels into the Connecticut River Watershed

Michelle D. Babione
Silvio O. Conte National Fish and Wildlife Refuge, US Fish & Wildlife Service
52 Avenue A, Turners Falls, MA 01376 USA
T: 413-863-0209 F: 413-863-3070 E: michelle_babione@fws.gov

Donald H. Pugh
Conte Anadromous Fish Research Center, US Geological Survey
1 Migratory Way, Turners Falls, MA 01376 USA

Zebra mussels were first discovered in North America fourteen years ago. Since then, they have spread to 22 states. Where they are located, their prolific reproductive rates allow them to spread rapidly downstream. Because infestation to unconnected waters is primarily through human dispersal (such as transporting boat trailers), information and education, coupled with management, is a primary tool for combating the invasion of zebra mussels across watersheds. A major prevention effort, the 100th Meridian Initiative, is in place in the Midwest to prevent the spread of zebra mussels across the continental divide. In the Northeast, the western divide of the Connecticut River watershed provides a complete North/South land barrier to the eastward migration of the zebra mussel in the United States. While the Connecticut River watershed is currently un-infested, zebra mussels are already as close as the Twin Lakes in north-eastern Connecticut and Lake Champlain in Vermont. Using GIS, waters of the Connecticut River watershed were prioritized based on boater use and access, proximity to existing infestations, the possibility for infesting large areas, connectivity, and limnological parameters. Important aquatic resources, including Atlantic salmon restoration areas, were also included in the analysis. While this assessment will serve as a tool to target resources, the success of defending this area against the impending threat of zebra mussels will depend upon coordinated strategic efforts of a regional coalition of state and federal agencies, water-based utilities, boating organizations, lake/pond/watershed organizations, and researchers. The Silvio O. Conte National Fish and Wildlife Refuge, which works on conservation issues at a landscape level across the entire Connecticut River watershed, proposes to initiate and coordinate this effort.

NOTES

Provisions of the National Aquatic Invasive Species Act of 2003 Relating to the 100th Meridian Program

Mark Sytsma
Center for Lakes and Reservoirs, Portland State University, PO Box 751, Portland OR 97207 USA
T: 503-725-3833 F: 503-725-383 E: sytsmam@pdx.edu

The National Aquatic Invasive Species Act (NAISA) of 2003 amends section 1202 of the Nonindigenous Aquatic Nuisance Species Prevention and Control Act of 1990. the Act authorizes the National Aquatic Nuisance Species Task Force to expand the 100th Meridian information and education program directed at recreational boaters in State from which watercraft are transported westward. The Act requires that the Task Force:

- survey owners of watercraft transported westward across the 100th meridian to determine the States of origin of most such owners,
- provide information to owners about the importance of cleaning watercraft crarring live organisms before transporting them,
- support education information programs of the States of origin to ensure that the State programs address westward spread.

The Act appropriates $750 000 to the US Fish and Wildlife Service to implement the activities of the 100th Meridian Program. The provisions of the NAISA that address westward spread of zebra mussels and other aquatic invasive species are widely supported in the western states, where efforts are underway to educate boaters about the risks of transport of invasive species on boats. The legislation focuses education activities in source states and therefore will support and enhance effectiveness of efforts to prevent westward movement of aquatic invasive species.

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NOTES

Aquatic Nuisance Species Awareness of Anglers in Northern Wisconsin and the Upper Peninsula of Michigan

Margaret M. Kulwicki, *Sadie K. Rosenthal and David M. Lodge*
University of Notre Dame
T: 574-631-4153 E: mkulwick@nd.edu

Anglers have probably spread freshwater nuisance species (ANS) through the release of live bait and the transport of attached organisms on boats. Educational efforts have therefore been implemented to promote angler awareness and encourage behaviors that minimize the risk of spread. In summer 2002, we conducted oral surveys of anglers at boat landings. To assess angler ANS awareness and behavior in northern Wisconsin and the Upper Peninsula of Michigan we asked questions about species awareness, bait choice and disposal, boat inspection, and educational sources. We also surveyed bait shop employees to determine their awareness of ANS, their impact on angler bait choice, and their willingness to educate anglers who purchase live bait.

We focused on five current and potential ANS in northern Wisconsin and the Upper Peninsula of Michigan: the rusty crayfish (*Orconetes rusticus*), Eurasian watermilfoil (*Myriophyllum spicatum*), the round goby (*Neogobius melanostomus*), zebra mussels (*Dreissena polymorpha*), and the Eurasian ruffe (*Gymnocephalus cernuus*). A total of 62 anglers were surveyed: 33 from Wisconsin, 14 from Michigan, 12 from Illinois, and 1 each from Minnesota, Indiana, and Ohio. Awareness (ranging from simply having heard of a species to knowing about their ecological and economic impacts) of ANS was higher for anglers from Michigan than for anglers from Wisconsin or Illinois. Comparing awareness for different species we found that for all three states, a high percentage of anglers knew about zebra mussels relative to other species: 91% of anglers from Michigan, 83% from Wisconsin, and 77% from Illinois knew about zebra mussels. In all three states, the round goby and the Eurasian ruffe were the least known species. Neither of these two species has been identified in the inland waters of Northern Wisconsin or the Upper Peninsula of Michigan.

90% of anglers stated they use live bait. For these anglers, most commonly used baits are worms (96%), fish (82%), leeches (78%) and crayfish (5%). 36% of these anglers reported that they had released live bait into the water. 65% of anglers stated that they check their boat for vegetation and/or animals when they exit lakes.

When asked how they learned of ANS, anglers named diverse resources. 89% of anglers reported that they gained awareness through reading signs posted at boat accesses, 60% through word of mouth, 53% from DNR fishing regulation manuals, 52% from outdoor magazines, 50% from classes/self study, 47% from newspapers, 31% from television, and 11% from the internet.

From the angler surveys we found that 91% of anglers who use live bait (n=55) purchase it from bait dealers in the Great Lakes region. Results from surveys of 20 bait shops indicate that bait shop employees have the opportunity to influence angler bait choice: 65% stated that over half of their customers seek advice. Employee ANS awareness was high: 95% of bait shop employees knew of at least one ANS. Further, 90% expressed willingness to provide their customers with educational materials on ANS. However, only 25% stated they currently have information on ANS in their bait shops.

Our results show that most anglers have some awareness of ANS. This suggests that warning signs and other outreach materials are effective in educating anglers and may promote angling behavior that reduces the spread of ANS (e.g., proper bait disposal and boat inspection). Because bait shop employees have high ANS awareness, contact with anglers, and willingness to provide educational materials to their customers, bait shops may be an underused resource by which to educate anglers about ANS.

NOTES

A Pilot-Scale System for the Treatment of Ships' Ballast Water Using Hydroxyl Medicament

Xiyao Bai, *Zhitao Zhang, Xiaojian Zhou, Mingdong Bai, Bo Yang, Chengwu Yi*
Environmental Engineering Research Institute, Dalian Maritime University, Dalian 116026, Liaoning, P. R. China
E: hjs@dlmu.edu.cn

The high dissolved hydroxyl concentration is formed using the strong dielectric barrier discharge and its kill principles are introduced in paper, the title "Kill Harmful Microorganisms in ship's Ballast Water Using Hydroxyl Radical". In this paper, a pilot-scale system for the treatment of ship's ballast water and its experimental results are discussed.

High-concentration hydroxyl radical is produced in Hydroxyl generator 3, and then is injected into dissolved unit 8 to form high dissolved hydroxyl medicament. The ratio concentration of OH* medicament reaches the threshold value of 0.65mg/L in the main pipeline of the ballast water. The introduced microorganisms are killed along a 6 m long main pipe, 10 m long is enough. In this system, the flow rate of ballast water is 20 t/h, the flow velocity is1.6 m/s, the sample point is along 6 m long of main pipe.

The ship's ballast water in this system is taken from the Dalian port, Liaoning Province, P.R. China. The Phytoplanktons, Zooplanktons and Germs are as follows. Phytoplankton: Chloreua Pyrenoidesa, Chaetocers, Peridinium. Zooplankton: Euplotes. Germ: Pseudomonas, Flarobacterus, Vibrio, Acinetobacter, Escherichia, Alcaligenes, Staphyloccus.

Because of low content of the monoplast algae and germs in ship's ballast water, 2216E liquid nutrient medium is injected into a glass tank of 1.5m^3 for the enrichment culture of the algae and germs which are enriched into 2°¡$10^{12}/m^3$ and 4°¡$10^6/m^3$ respectively. When the ratio hydroxyl

concentration is 0.65 mg/L, the germs, monoplast algae and Zooplanktons are not tested in the water sample of 150 mL. The introduced microorganisms can be killed within 4.1 s also along the main pipe of the ballast water.

The conclusions that hydroxyl radical kills the introduced microorganisms is as follows.

1) Lipide peroxidation degree of monoplast algae increases 2 times in the experiment resulting in death.

2) Hydroxyl radical has a strong destruction effect on monosaccharide, amylose, protein, DNA and RNA in the plankton cell.

3) Hydroxyl radical has a obvious destruction to the activity of CAT, POD and SOD in antioxidase system of Plankton. Therefore, the first is the loss of enzyme activity. And then, the enzyme as a protein is oxidized and decomposed by hydroxyl radical. Especially, antioxidase system is destroyed, which effect vital activity of the cells so that the cell die.

The content of phosphate and nitrate has a little raise of 11.5% and 17.4% respectively. The content of nitrite and ammonium salt has a obvious decrease from 66.6 ug/L to 1.1 ug/L and 79.8 ug/L to 0.4ug/L respectively, which are oxidized and decomposed by hydroxyl radical. The products have Nitrate to lead to a little increase of Nitrate. Nitrite and ammonium salt have a harmful effect on aquatic, especially Nitrite can oxidized the low-iron hemoglobin into the high-iron hemoglobin resulting in the loss of function to carry oxygen. Therefore the water quality is obviously improved after the treatment of hydroxyl radical.

The decrease of 50% turbidity, no COD tested, 2 times raise of TOC indicated that hydroxyl radicals oxidize and decompose the organics in water into COD and OC is difficult to be tested. In addition, The oxygenolysis of hydroxyl radicals to the cell remains also contributes to the increase of TOC content.

NOTES

Geographic Variation in the Genetic Variation of *Myriophyllum spicatum* Investigated by Random Amplified Polymorphic (RAPD) Markers

Karen L. Martin and ***Charles W. Boylen***
Darrin Fresh Water Institute and Rensselaer Polytechnic Institute, Troy, NY 12180-3590 USA
T: 518-276-8430 F: 518-276-2162 E: boylec@rpi.edu

Joseph P. Mascarenhas
Department of Biology, State University of New York at Albany, Albany, NY 12222-0001 USA

The Eurasian watermilfoil, *Myriophyllum spicatum*, is an invasive plant that has spread throughout the United States by fragments from waterfowl and boats. Although originally introduced into North America possibly prior to the last century, little is known about the genetic variation in this plant species in its invaded territory. Two studies conducted on the genetics of Eurasian watermilfoil using plant fragments taken from Minnesota lakes found only two genotypes and no within-lake diversity; it also appeared that seeds did not contribute to the genetic diversity. The species has been present in New York State prior to 1960; however, no studies of the genetic diversity here have been conducted. Nor has the genetic contribution of the seed been investigated as a source of genetic diversity. This study is the first investigation of the genetic variability found in lakes in New York State and the first to compare the genetic variability found in seed-grown fragments to plant fragments from the same lake. Random amplified polymorphic DNA (RAPD) markers were used to detect genetic variation in plant fragment samples and seed-grown fragment samples. Ten primers were used and the amplification resulted in 115 well-defined bands in the 300–2000 base pair range. Popgene was used to determine the percentage of polymorphic loci and allowed the construction of a dendrogram based on Nei's genetic distance. The percentage of polymorphic loci was defined as the molecular weight bands that showed both a presence and absence of bands out of the total number of bands. This percentage was calculated for both the seed-grown and plant grown fragments in each lake. The percentage of polymorphic loci ranged from 22 to 41%. This level of genetic variability is consistent with the genetic variability found in all plants. Increasing sample size increased the percentage of polymorphic loci from 61 to 81%. Grouping the seed-grown and plant fragments together increased the percentage of polymorphic loci in all the lakes. This indicates that there are genetic differences between the plants from a lake and the seeds germinated from a lake. Therefore seed germination could add genetic variability to the population in the lake. In the dendrogram of the seed-grown fragments the Rensselaer County samples formed their own subgroup. The other seed samples formed another subgroup. In contrast the plant fragment samples from Rensselaer County samples did not form a subgroup. The two different dendrograms corroborates genetic differences in the plant and seed-grown samples as indicated by the increase in percentage of polymorphism in the two sample groups. Since the plant samples do not form geographical subgroups, it appears that there are multiple genotypes in New York State. Unlike plants found in Minnesota, Eurasian watermilfoil in New York State consists of more than two genotypes, leading to the conclusion that there have been multiple introductions in the state. Seed-grown fragments could add to the genetic variability in lake populations. Increased genetic variability could make Eurasian watermilfoil a more aggressive and persistent invader in New York Lakes.

NOTES

Zebra Mussel Control Efforts on The St. Croix National Scenic Riverway, Minnesota and Wisconsin

Byron N. Karns
St. Croix National Scenic Riverway, National Park Service, P.O. Box 708 St. Croix Falls, WI 54024 USA
T: 715-483-3284 Ext. 616 F: 715-483-3288 E: Byron_Karns@nps.gov

Nick Rowse
US Fish and Wildlife Service, Twin Cities Field Office, 4101 E. 80th Street Bloomington, MN 55425 USA

In 1992, zebra mussels were discovered in the Mississippi River as it flows through Minneapolis. Downstream lies the St. Croix National Scenic Riverway, a unit of the National Park System. Renown for its recreational and biological resources, the St. Croix River is nationally significant for its richness and abundance of freshwater mussels (~40 species). With the greatest diversity of unionids in the Upper Mississippi watershed, the Riverway will be severely impacted by a zebra mussel infestation.

Since that discovery of zebra mussels on the Mississippi River, the National Park Service has led an interagency task force (US Fish and Wildlife Service, Minnesota/Wisconsin Departments of Natural Resources, MN/WI Boundary Area Commission, Minnesota Sea Grant, Great Lakes Indian Fish and Wildlife Commission, St. Croix Marina Association, and others) designed to halt or slow the spread of zebra mussels (*Dreissena polymorpha*) into the St. Croix Riverway. The prevention efforts include education and information, access management, monitoring, planning for remediation and research. A new element for the task force since 2000, has been the formation of an agency-staffed SCUBA dive team to monitor the river from under the surface. With the creation of a dive team staffed with members of the National Park Service and the Fish and Wildlife Service, the river can be surveyed by trained biologists and experts, all of whom sit on the task force. Thus, monitoring conclusions and recommendations can be made with a unique degree of first-hand information.

The creation of a St. Croix dive team could not have come at a more critical time in the history of the zebra mussels on the Riverway. Zebra mussels have been found attached to a small number of boats in the St. Croix since 1995 and individual mussels have been discovered scattered in small numbers on substrate along the lower 25 miles of river. While these animals have had an individual presence on the river for a number of years, a reproducing population has never been discovered in the St. Croix River. Unfortunately, that changed during the summer of 2000.

Strong evidence has been found for zebra mussel reproduction located within the lower ~16 miles of the river. The source of reproduction has yet to be pinpointed, but the resulting settlement of juvenile mussels is very disturbing, if not unexpected. Armed with the unfortunate knowledge that the mussels have arrived, the task force has begun the painful chore of creating recommendations for policy makers and agency managers. The river may indeed be at a juncture in its ecological history. What actions are taken may be critical to the plants and animals that call the river home and a recreating public that enjoys the many wonderful aspects of this nationally protected waterway. The management issues surrounding zebra mussels are complex and may be controversial. This presentation focuses on the multi-agency actions designed after 2000, and features field activities in 2001 and 2002.

NOTES

Population Genetic Structure of Zebra Mussels in North America: Implications for Management

***Richard F. Lance**, Herbert L. Fredrickson and Edward J. Perkins*
Environmental Laboratory, US Army Research and Development Center, 3909 Halls Ferry Road, Vicksburg, MS 39180, USA
T: 601-634-3971 F: 601-634-4002 E: lancer@wes.army.mil

We are studying the population genetic structure of zebra mussel (*Dreissena polymorpha*) populations from across much of their North American range. We have applied an amplified fragment length polymorphism (AFLP) methodology to samples from the Arkansas, Mississippi, and Tennessee River systems, the Great Lakes, and other sites. On-going analyses are finding genetically diverse zebra mussel populations with statistically significant interpopulation genetic differentiation. As populations are added to our growing genetic dataset, patterns indicative of primary dispersal mechanisms may be elucidated. Genetically diverse populations are more likely to be resilient to control efforts, more likely to adapt to new environmental stressors, and more likely to successfully colonize new sites.

NOTES

Westward Ho!: Zebra Mussels on the Move

Cindy M. Messer *and Tanya C. Veldhuizen*
California Department of Water Resources, Division of Environmental Services, 3251 S Street, Sacramento, CA 95816 USA
T: 916-227-7545 F: 916-227-7554 E: cmesser@water.ca.gov

The freshwater zebra mussel (*Dreissena polymorpha*) is an extremely invasive species that has the potential to cause severe economic and ecological impacts in California. This species is highly adaptable and would flourish in the waters of California, causing similar detrimental effects as it has in the Midwestern and East coast states and in several Canadian provinces. For California, the most likely vector of zebra mussels is long-distance transport of watercraft leaving states with contaminated lakes and rivers and then entering California water systems.

The Zebra Mussel Detection and Outreach Program, funded by CALFED (a consortium of State and Federal government agencies) and the California Department of Water Resources, is a multi-year project aimed at preventing the establishment of zebra mussels in California. The goals of this program are to: 1) conduct a risk assessment of waterbodies in San Francisco Bay watershed, 2) conduct early detection monitoring in the field, 3) set-up a centralized reporting system by which detection of zebra mussels can be reported and conveyed to all interested parties, 4) establish a rapid response plan for California, and 5) educate the public about zebra mussels.

The objective of the risk assessment is to determine the areas at high risk for zebra mussel introduction and establishment in the Central Valley watershed. Risk of establishment was based on habitat suitability (e.g., availability of food resources, dissolved calcium, and optimal temperature range) and the likelihood of introduction (e.g. the popularity of a waterbody with out-of-state boaters). Based on the results of the risk assessment, we are conducting an early detection monitoring program in high risk lakes and rivers. We monitor for the presence of larval zebra mussels using artificial substrates samplers that are suspended from docks, piers, and other structures and checked on a monthly basis. Early detection greatly increases the probability of eradicating a zebra mussel population. We established a central reporting location to receive and distribute information on zebra mussel sightings and prevention activities. In the event zebra mussels are detected, we are nearing the completion of a rapid response plan to provide guidelines for zebra mussel sighting confirmation, containment, eradication, and public notification. Implementation of the rapid response plan will be a collaborative effort between State and Federal agencies and private and public interest groups. We also implemented a public outreach and education program to educate the public about the severity of the potential impacts, measures to prevent zebra mussel introduction, and how to identify zebra mussels and report sightings. Educational materials are available at marinas, bait shops, visitor centers, California Welcome Centers, rest stops, and online.

NOTES

The National Aquatic Nuisance Species Clearinghouse and Searchable Electronic Database

Charles R. O'Neill, Jr. *and Diane J. Oleson*
National Aquatic Nuisance Species Clearinghouse, Morgan II, State University College, Brockport, NY 14420 USA
T: 585-395-2638 F: 585-395-2466 E: cro4@cornell.edu

Stakeholders interested in the introduction, spread, potential impacts, and control of aquatic nuisance, non-indigenous, and invasive species require timely, reliable scientific information and fast, easy access to published research pertaining to such organisms. Since 1990, they have been able to obtain such information relating to the zebra mussel from Sea Grant's Zebra Mussel Information Clearinghouse. For seven years, the Clearinghouse was "just" a zebra mussel Clearinghouse, with North America's most extensive technical library of published research, "grey literature," and other relevant documents pertaining to all facets of the zebra mussel issue. That is the past.

Extensive and exciting changes have been taking place since mid-1997, resulting in the name change to the "National Aquatic Nuisance Species Clearinghouse" and a revised mission to facilitate and coordinate aquatic nuisance, nonindigenous, and invasive species information (ANS/NIS) sharing among researchers throughout North America and world-wide; provide continuity to the timely dissemination of findings of ANS/NIS research projects; and facilitate ANS/NIS prevention and control technology transfer between researchers and stakeholder audiences. The Clearinghouse serves as a major link between the research community and a wide array of university, government agency, industrial, and special interest stakeholders, and plays a high-profile role as a primary nexus for identifying completed, current, and proposed ANS/NIS research activities and for linking researchers with similar interests.

Both marine and freshwater aquatic nuisance, non-indigenous, and invasive species throughout the Gulf of Maine, Northern Atlantic, Mid-Atlantic, Southern Atlantic, Gulf of Mexico, Central and Northern California, Pacific Northwest, and Great Lakes regions, and North American inland river and lacustrine systems are now addressed. The Clearinghouse is continually updating its library and searchable database of over 5800 documents, which include specific collections on 28 organisms, as well as biological macrofouling, ballast water, aquatic exotic organism, and invasive species policy issues.

All Clearinghouse information is accessible to any researcher, agency, industry, utility, student, or other individual or group having need of the information via electronic mail, fax, toll- or toll-free telephone, written requests, or visits to the Clearing-house. A new, keyword outline and full text searchable electronic database of the Clearinghouse's Technical Library Bibliography is now available on the Clearinghouse's revamped, user-friendly World Wide Web home page (www.aquaticivaders.org). Citations include: author(s), title, document source and date, an annotation, type of publication, document length, language in which the document is written, whether the document is available from the Clearinghouse or direct from some other source, and the copying/mailing fee from the Clearinghouse. Most documents are available directly from the Clearinghouse on interlibrary loan and can be ordered via a convenient on-line "shopping basket." The Web site also contains a series of detailed maps charting the range expansion of the zebra mussel and the "quagga" mussel in North America since 1989, information on a number of other informational and educational materials available from the Clearinghouse as well as extensive "hot links" to other ANS/NIS Web sites.

The Clearinghouse's quarterly publication, *Aquatic Invaders*, presents papers on a variety of ANS/NIS and related topics such as: research, policy, impacts, new introductions, ballast water, education and outreach, and control measures as well as highlighting library holdings, useful Web sites, and meeting announcements.

The Federal Aquatic Nuisance Species Task Force, the US Army Corps of Engineers Zebra Mussel Research Program, the Great Lakes and Western Panels on Aquatic Nuisance Species, the Western Zebra Mussel Task Force, and numerous other federal, state, and inter-national agencies and institutions have utilized the Clearinghouse as a major channel for extending information on zebra mussel, aquatic nuisance, nonindigenous, and invasive species spread, research, and policy initiatives to all interested audiences.

Does Byssal Detachment Overestimate Sensitivity of Mussels to Toxic Compounds?

Sanjeevi Rajagopal *and Gerard van der Velde*
Department of Animal Ecology and Ecophysiology, Faculty of Science, University of Nijmegen
Toernooiveld 1, 6525 ED Nijmegen, The Netherlands
Tel: 31-24-365 2364 Fax: 31-24-365 2134 Email: raju@sci.kun.nl

Henk A. Jenner
KEMA Power Generation and Sustainables, PO Box 9035, 6800 ET Arnhem, The Netherlands

Mussels are sedentary organisms attached to solid substrata by means of byssus threads. Due to their sedentary habitat, mussels have gained importance as monitors of environmental water quality and also as fouling organisms clogging cooling water conduits of industries. Mussels detached from their substratum tend to reattach using freshly secreted byssus threads. In bioassays using mussels, if the organisms are in an unattached status, increased byssogenic activity would expose their soft body parts to the toxic compound used. In the present study, we used two prominent mussel species namely the marine mussel, *Mytilus edulis* and the brackish water mussel, *Mytilopsis leucophaeata* as model organisms. Sensitivity of the organisms to a candid biocide (chlorine) is tested using attached and unattached mussels in a laboratory flow-through system. Results show that detached mussels are 24–29% more sensitive than byssally attached ones. Detached mussels also showed higher oxygen consumption, filtration rate, foot activity index, byssus thread production and byssogenesis index. A review of literature showed that most of the toxicity data (heavy metals, biocide etc.) generated using mussels in unattached state. The data, therefore, are probably not realistic and represent overestimation of the toxicity of the compound tested. The present study suggests the importance of maintaining mussels in their native attached status, while undertaking bioassays.

NOTES

Cost Analysis of Mandatory Ballast Water Exchange in the United States

***Elena Ryan**, Kathy Moore, Chris Abrams, Kevin Montgomery and David Houser*
US Coast Guard (G-MSR), 2100 2nd Street SW, Room 1400, Washington, DC 20593-0001 USA
T: 202-267-1050 F: 202-267-1050 E: eryan@comdt.uscg.mil

The United States Coast Guard is currently engaged in a rulemaking effort to make the provisions of the Ballast Water Management regulations of 33 CFR 151:2000 – 2065 mandatory for all vessels entering US waters. The poster presentation will document the cost analysis for the cost born by the shipping industry to implement these mandatory provisions.

Previous studies of ballast water as a vector for the introduction of aquatic invasive species have taken various approaches to characterizing the amount of ballast water entering the US waters as a result of cargo operations. This analysis attempts to capture the amount of ballast water that would need to be exchanged by vessels to which these new federal regulations would be applicable. In contrast to previous work, this analysis does not restrict itself to a representative sampling of commercial vessels, nor is it a characterization of activity confined to a particular US port zone.

Specifically, the poster will present an analysis based on vessel arrival data for all commercial vessels inbound to the US. All of these arrivals are assigned a vessel type, based on its size, and service. Data published in Lloyd's Register of Shipping is used to characterize each arrival in terms of vessel particulars in order to establish on average, how much ballast water is on board and the capacity of ballast pump likely to be used for exchange. In addition, arrival data is used to determine the vessel's transit and whether the transit takes the vessel more than 200 nautical miles from any land, permitting the exchange of mid-ocean water. If the transit does permit an exchange of ballast water, the probability of performing an exchange is applied based on wave height data published for specific sea areas. Wave height is being used in this analysis as a lower limit estimate of the sea states permissible for completing exchanges as determined by either flag or class societies based on vessel type. The hour-cost of operating the ballast pump for the required volume exchange is calculated for all of the vessel entries for each of two years of arrival data. Pump hours are influenced both by the size of the vessel, as well as whether the vessel is more suited to exchange by the sequential method or the flow-through method. In addition, a annual repair/maintenance cost that is a fraction of the ballast pump's capital cost is added for the wear and tear inflicted on the pump by the additional operating time. Finally the one time cost, per vessel, of the development of a vessel-specific ballast water management plan is added to complete the analysis.

The poster presentation will present all the assumptions used to develop the analysis as well as the vessel-type specific average costs for ballast water exchange, both on a per-trip basis and an annual basis for vessels trading in the US.

NOTES

A Flow-Through Field Study Demonstrating Proactive Control of Zebra Mussel Plankton by an Environmentally Friendly Starch-Based Reagent

A. Garry Smythe *and Cameron L. Lange*
Stantec Consulting Services Inc., 140 Rotech Drive, Lancaster, NY 14086-9755 USA
T: 716-759-1200 F: 716-759-1489 E: gsmythe@stantec.com

The Barkley Resources Group (BRG) has developed a product composed of a mixture of food-grade cornstarch and water. The mixture is activated by an indirect exposure to BRG's proprietary technology. When activated BRG refers to the mixture as a reagent. The reagent rapidly degrades through natural processes, such as bacterial decomposition when released to the environment. The BRG was interested in evaluating the starch reagent as a proactive control (moluscicide) for zebra mussel (*Dreissena polymorpha*) plankton. In 2000, BRG engaged scientists from Stantec Consulting Services Inc. (Stantec), who completed static tests using planktonic mussels from the lower Mississippi River in a paired treatment-control test protocol. These in-field exploratory tests demonstrated 100 percent mussel mortality in 44 hours or less using whole-product concentrations of 3 mg/L, 5.6 mg/L and 6.9 mg/L.

Subsequent to these promising test results, BRG wanted to conduct a field study under flow-through conditions where raw river water and entrained mussels would be used. This test approach results in raw water and reagent being discharged into the environment. So, as a preliminary to requesting permission to use a facility for a flow-through study, seven day replacement toxicity tests on fathead minnows and ceriodaphnia were completed in Stantec's Ecotoxicity Laboratory, the tests following United States Environmental Protection Agency (USEPA) protocols. The results of these toxicity tests indicated LC_{50}s for the fathead minnows and ceriodaphnia were 99 000 mg/L and 59 000 mg/L, respectively. These data were reviewed by the USEPA and Louisiana Department of Environmental Protection (LDEQ), and the LDEQ permitted the test to be conducted at a power plant on the lower Mississippi River. However, as part of the permit the LDEQ required a whole effluent toxicity test (WHT) of the facility discharge at the initiation of the BRG flow-through tests. The flow-through study was initiated in October of 2002 and Stantec subcontracted a laboratory in Baton Rouge to complete the WHT that included the reagent discharge. The WHT report indicated no effect on the *Daphnia magna* or fathead minnows used in the effluent tests.

In the flow-through test zebra mussel veligers and post-veligers in the treatment leg of the test-stand were exposed to reagent doses ranging between approximately 4 mg/L and17 mg/L whole product. The morality rate was 100% for mussels exposed for 72 hours or more. The mortality rate for mussels exposed for 21 hours was 69%, while it was only 15% or less in the untreated controls. Overall, these data indicate that the generally non-toxic starch-based reagent proactively provided 100% control of veliger and post-veliger zebra mussels.

NOTES

Chinese Mitten Crab (*Eriocheir sinensis*) Reporting System and Monitoring Program in California

Erin Williams
US Fish and Wildlife Service , 4001 N. Wilson Way, Stockton, CA 95205-2486
T: 209-946-6400 x 321 F: 209-946-6355 E: Erin_Williams@fws.gov

The US Fish and Wildlife Service, with support from the Interagency Ecological Program, is conducting a survey to determine the distribution and relative abundance of the Chinese mitten crab (*Eriocheir sinensis*) in the San Francisco Bay and its tributaries, the Delta, and the Sacramento and San Joaquin rivers and their tributaries. This survey includes sampling of field sites for mitten crab distribution and a reporting system, which allows citizens to report crab sightings.

The reporting system began in April 2001 and consists of an online reporting form, toll-free phone number and a prepaid postage mailer attached to an identification brochure. More than 200 reports have been received from private citizens and civil servants in the study area. Reports are solicited from fishermen, agency, university and private sector scientists, water management and flood control districts, county agriculture offices, and the public. All reports are verified for the accuracy of the information with approximately 15% being confirmed in the field. Based on the numbers of submissions to the reporting system, we believe this is a viable tool for monitoring the mitten crab population and focusing sampling efforts. For more information about the program, please visit: http://www.delta.dfg.ca.gov/mittencrab/index.html. Reports are emailed to mcrabman@delta.dfg.ca.gov or the toll free number at 1-888-321-8913.

The program also includes a summer monitoring program of various freshwater areas, primarily upstream of the San Joaquin Delta. This component provides information to help determine distribution and relative abundance of sub-adult mitten crabs. Sampling methods include a combination of "crab condos," baited traps, and hand catching. The monitoring program provides key information for mitten crab year class strength and location of upstream rearing areas.

At each site water temperature, electroconductivity, stream velocity, channel width, substrate type, vegetation type (bank and instream), and percent vegetative cover are recorded. Mitten crabs and molts are enumerated, measured and sexed. To date, crabs have been found in sandy, muddy and rocky substrates, in water temperatures varying from 17.7 °C to 26.2 °C, and in streams with velocities from 0.01 m/s to 0.64 m/s.

NOTES

Olfactory Sensory Responses of Reproductive and Non-reproductive Female Round Gobies (*Neogobius melanostomus*) Support the Presence of Sex Pheromones

Andrea J. Belanger, *Linda D. Corkum and Barbara Zielinski*
Department of Biological Sciences, University of Windsor, Windsor, ON N9B 3P4 Canada
T: 519-253-3000 x 4766 F: 519-971-3609 E: belange@uwindsor.ca

Weiming Li
Department of Fisheries and Wildlife, Michigan State University
13 Natural Recources Building, East Lansing, MI 48824-1222 USA

Alexander P. Scott
Weymouth Laboratory, The Center for Environment, Fisheries and Aquatic Sciences
The Nothe, Barrack Road, Weymouth, Dorset, UK DT4 8UB

The round goby is an aggressive and prolific nonindigenous bottom-dwelling fish species that threatens native economically and ecologically important fish in the Great Lakes. It easily takes over the optimal spawning habitats of native benthic species and eats eggs and young of other fish. The parental male round goby maintains and guards a nest into which many females deposit eggs. We hypothesize that nesting round goby males release a sex pheromone to attract females to the nests.

In this study, we established the sensitivity of the olfactory system in female round gobies. Physiological responses to water conditioned by male round gobies were assessed through electro-olfactogram (EOG) recordings. The EOG bioassay has been commonly used to identify odorous compounds subsequently proven to be pheromones in various fish species. We collected and concentrated water released by male gobies and examined EOG responses from reproductive and non-reproductive female round gobies. The largest EOG responses were recorded from reproductive females to the odour of reproductive males. In addition, reproductive females responded significantly greater than non-reproductive females to water conditioned by reproductive and non-reproductive males. Once a physiological response was recorded from the conditioned water, hydrophobic components were separated with a SEP-PAK cartridge and then fractionated using high performance liquid chromatography. Each fraction was tested for physiological activity using the EOG bioassay. Again, reproductive females responded strongly to fractions that originated from the reproductive male conditioned water with specific fractions showing consistent elevated olfactory sensory activity.

Overall, these results imply that females ready for spawning activity show increased olfactory mediated sensory responses to odours originating from potential mates, and that EOG can be used with biochemical isolation techniques for sex pheromone identification.

NOTES

Isolation of Reproductive Pheromones Used by the Round Goby, a Great Lakes Invasive Fish Species

***Wesley J. Arbuckle**, Lynda D. Corkum and Barbara Zielinski*
Department of Biological Sciences, University of Windsor, 401 Sunset Avenue, Windsor, ON N9B 3P4 Canada
T: 519-253-3000 x4766 F: 519-971-3609 E: arbuck1@uwindsor.ca

Weiming Li
Department of Fisheries and Wildlife, Michigan State University, 13 Natural Recources Building
East Lansing, MI 48824-1222 USA

Alexander P. Scott
The Center for Environment, Fisheries and Aquatic Sciences, Weymouth, Dorset, UK

The round goby is a nonindigenous fish in the Great Lakes that has an aggressive nature and multiple spawnings per season. The success of this invasive species may be in part due to pheromonal communication between male and female round gobies during reproduction. Male round gobies may secrete substances (pheromones) to the outside that are received by female round gobies and that attract females to the nests of males. Physiological studies have implied that round goby reproductive pheromones may be steroidal compounds (Murphy et al. 2001 J. Chem. Ecol. 27: 443–470). Investigation as to the structure of the steroids being produced by the male testis of the round goby is a current undertaking. Gonadal tissue is incubated with radioactive steroid precursors. Preliminary experiments with incubations of the testis and its associated cement gland have shown that the male gonad is producing steroids from radioactive androstenedione, testosterone, and 17-hydroxyprogesterone. Tritiated androstenedione is transformed into at least seven metabolites by the testes of mature males. One of these metabolites has been identified as etiocholanolone. Previous studies by Murphy et al. (2001) have shown that this androgen is a potent olfactorant. Another metabolite has been identified as 11-keto-etiocholanolone. We are proceeding with biochemical isolation and testing of physiological and behavioral parameters to identify reproductive pheromones used by the round goby. This research will provide information regarding the exact nature of the steroidal communication between male and female round gobies. The outcome of this research will ideally lead to the development of a targeted, environmentally benign pheromone-based technology to disrupt the reproductive habits of the round goby.

NOTES

Impacts of an Invertebrate Invader on Phytoplankton Communities in Canadian Shield Lakes

Andrew M. Paterson and ***Norman D. Yan***
Ontario Ministry of Environment, Dorset Environmental Science Centre, PO Box 39, Dorset, ON, P0A 1E0 Canada
T: 705-766-2951 F: 705-766-2254 E: andrew.paterson@ene.gov.on.ca

Jennifer G. Winter
Ontario Ministry of Environment, 125 Resources Road, Etobicoke, ON M9P 3V6 Canada

Biotic exchanges represent one of the most significant threats to aquatic biodiversity in temperate regions. There is clear evidence that invading species can alter freshwater community structure and diversity in temperate lakes. In a 20-year study of Harp Lake, Ontario, a small inland lake on the Canadian Shield, the establishment of the spiny water flea (*Bythotrephes*) resulted in unprecedented changes in zooplankton species richness and size structure. However, the response of phytoplankton to these changes is unknown, despite circumstantial evidence that algal blooms have increased in the years following invasion.

Phytoplankton communities are influenced by many stressors, including climate change, acid deposition, and nutrient enrichment from point and diffuse sources. Furthermore, recent evidence in the Great Lakes suggests that selective grazing by exotic invaders may contribute to the production of deleterious algal blooms. Disentangling the relative influence of these factors on phytoplankton structure is complicated as they may act synergistically and antagonistically in lakes, and climate may play a confounding role. We address these concerns by examining long-term trends in the phytoplankton community of Harp Lake before and after a recent invasion by the freshwater zooplankter, *Bythotrephes longimanus*. We use a multivariate statistical procedure to examine the relative importance of these stressors on phytoplankton community structure in Harp and two reference lakes over the past 20 years. Variance partitioning analysis estimates the fraction of the variation in community structure that can be explained by categories of environmental variables, as well as their interactive effects. The categories we have included in the analysis are physical and chemical variables (e.g., nutrients, light), and the structure of predator communities (e.g., impact of grazers), the latter being directly influenced by the *Bythotrephes* invasion in Harp Lake.

The following questions will be addressed: Did the structure of phytoplankton communities change significantly in Harp Lake following its invasion by *Bythotrephes*? Are long-term patterns in phytoplankton community structure driven more by changes in grazing pressure than by long-term changes in physical-chemical variables? Do different patterns emerge for Harp and the reference lakes?

NOTES

Aquatic Invasive Species in the Black Sea and Freshwater Environments in Georgia

Boris Bitsadze *and Jambul Gugunishvili*
Committee on Environmental Protection and Natural Resources
Parliament of Georgia, 8 Rustaveli Avenue 380018 Tbilisi Georgia
T: 995-32-92-2085 F: 995-32-25-3901 E: geoera@gol.ge

This abstract was not available at the time of printing.

NOTES

Invasive Fish: A Bangladesh Perspective

Amir Hossain
Institute for Environment and Development Studies, House 23, Road 10A, Dhanmondi, Dhaka, Bangladesh
T: 880-2-935-4128 F: 880-2-831-5394 E: iedsfoeb@accesstel.net

Invasive fish species were deliberately introduced in Bangladesh mainly in order to increase productivity. The most 'disastrous' invasive species of fishes are *Clarias gariepinus*, *Pangasius sutchi*, *Pangasius giganticus*, *Tilapia mossambica* and *Oreochromis niloticus*. And very recently came the dangerous Amazonian species the piranha. It is an irony for Bangladesh which is very much rich in wide variety of indigenous fish. These invasive species rapidly spread into the wetlands as 'biological explosives' due to recurring flooding. This has caused 54 indigenous fishes to become threatened within a very short period of time.

Invasive species that colonize in the natural or semi-natural ecosystems are also an agent of change, and threaten native biological diversity. As a sub-tropical country, Bangladesh is exceptionally rich in biodiversity. Bangladesh has almost all major types of flora and fauna characterized by high growth rate, high economic value, high market demand, etc. It would be wise if the authority could try to improve and popularize these indigenous species instead of indiscriminate introduction of invasive species in her wetlands.

The introduction of alien species has a long history in Bangladesh. Perhaps the first widely introduced species in Bangladesh is Water Hyacinth, *Eichhornia crassipes*, which was brought from Brazil during the British period. British ladies were fond of its flowers and brought it to Bangladesh for decorative purposes. At that time, nobody realized how vigorously this species could turn into an aquatic weed. The excessive fecundity and growth rate of these species created pressure on the carrying capacity of the habitat, and the ecosystem balanced itself by reducing the indigenous species diversity and population.

There has been recent controversy over piranha, which is well-known in many horror stories as a man-eating fish, so that if one were to fall in the water where piranhas are active they would probably not survive.

The vampire piranha is now being sold in the Market of Bangladesh. It became known, after conducting an inquiry, that a greedy businessman is cheating people by selling piranha as pomfret (locally called Rup-chanda). The cultivation of piranha is increasingly occurring in Bangladesh.

This invasive aquatic species is grown in huge quantities in the Amazon River in South America. It looks very innocent, as the size is almost like the sea chanda. Among all of the species, black piranha (*Ceralesmas nizar*) is the largest, most invasive and dangerous. It grows to a length of 45 cm and can weigh up to 2.2 kg. It has two fins on the backbone, and one fin at the end is fleshfull. Its teeth are small, hard, and sharp in both the upper and lower jaws and piranha can easily separate the flesh of any living being, man or animal. No one would survive if they fell to a group of them. They not only devour small and large fish, but also goats, cows, deer, horses and humans. A strong and healthy cow can be eaten completely by them in a few minutes. Except for bone, every other part of its victims is easily consumed. Birds and other creatures living along the banks of waterways also become the target of piranha.

From a census taken in Brazil it has become known that 1200 cows are eaten by piranha every year.

Considering the dangerous behavior of piranhas, cultivation and grooming of this species has been banned in many countries. China banned piranha in 2002 and it has also been banned in Japan.

The Bangladesh Geologist Society, the Zoology Department of Dhaka University, and the Fish Specialists of the country identified the piranha in a number of Dhaka fish market. They have demanded the ban of its import and cultivation immediately. They asserted that if piranha is not banned the aquatic environment of the country will seriously be destroyed. It is worth mentioning that a few years back the Bangladesh government banned another invasive fish species known as African Magur, which once imported and extensively cultivated. Civil societies have taken their unified position against the cultivation of that species to protect the environment, but unfortunately this dangerous species is still being sold in markets.

Salvinia molesta Growth Rates in an Urban Lake in the Plateau of Lagoa Santa, MG

Afonso Pelli
Departamento de Ciências Biológicas - Faculdade de Medicina do Triângulo Mineiro, Rua Frei Paulino, 30 - Uberaba/MG CEP 38025-180 Brazil
T: 55-34-3318-5424 E: apelli.oikos@mednet.com.br

Francisco A. R. Barbosa
UFMG–ICB, P.O. Box 486, CEP 30161-970, Belo Horizonte, MG Brazil

Eliot Taylor
Broadland Environmental Services Ltd. First Floor, Wensum House, 103 Prince of Wales Road, Norwich, Norflok NR1 1DW UK

Due to its high growth rates, *Salvinia molesta* has been considered a plague in various environments, causing damage and resulting in loss in the water quality. In Olhos d'Água Lake, this species covers approximately 20 to 40% of the water surface, depending on the time of the year. This study has the purpose of carrying out a physical-chemical characterization of the environment, besides measuring its growth rates, suggesting models that would be able to explain its variations. Collections were made in a fixed station, from February 1991 to March 1992, in order to measure the pH, the electrical conductivity, the dissolved oxygen, transparency, total alkalinity and the concentrations of ammonia, nitrite, nitrate, total nitrogen, orthophosphate and total phosphorus. The results show that there is a defined season for the growth rates, and the smaller rates are verified during the colder season of the year. The minimum and maximum values were, respectively, -0.019 and 0.061 for the liquid growth and 0.007 and 0.064 leaves produced (leaves per day), for the gross growth. The concentrations of orthophosphate, temperature and isolation were the determining parameters for the growth of *S. molesta* during the period of the study. The continuous enrichment of the lake must promote a considerable increase of the *S. molesta* biomass, jeopardizing the quality of the water and the various other communities in this environment. Environmental zoning, protection given to riparian forests and environment education programmes are suggested as adequate measures for reverting the state of degradation which can currently be observed.

NOTES

Effect of Simazine on the Reproductive Behaviour and Hatching Capability of Lymnaea Peregra (Muller) Under Laboratory Conditions

M. Nazrul Islam
Department of Zoology, University of Rajshahi, Rajshahi-6205, Bangladesh
T: 88-0721-750041-4119 F: 88-0721-750064 E: nazrul96@yahoo.com

Athol J. McLachlan
Department of Marine Sciences and Coastal Management, University of Newcastle upon Tyne, NE1 7RU UK

Gordon R. Port
Department of Agricultural and Environmental Science, University of Newcastle upon Tyne, NE1 7RU UK

The sub-lethal effects of the herbicide simazine on the reproductive behaviour and hatching capability of the snail, *Lymnaea peregra* (Muller) were studied. The pre-adult snails were kept in a variety of concentrations (10 50005g/L) of a herbicide *simazine* solution in dechlorinated tap water over a 9-week period. The herbicide treated snails produced significantly lower number of capsules/snail, total eggs/snail and eggs/capsule than those in the controls. However, there was no significant effect of the herbicide on hatching capability from the egg capsules in the snail. The experiment reflects that the quality of food and other environmental factors are important to the snail for greater survival and higher reproduction.

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