2006

ICAIS

14th International Conference on Aquatic Invasive Species

May 14 to 19, 2006
Key Biscayne, Florida

Hosted by the United States Geological Survey

USGS
science for a changing world

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U.S. Geological Survey

National Oceanic and Atmospheric Administration

National Sea Grant

International Joint Commission

U.S. Coast Guard

South Florida Water Management District

Pacific State Marine Fisheries Commission

National Park Service

U.S. Fish and Wildlife Service

Florida Fish and Wildlife Conservation Commission

Walt Disney World Company

Florida Department of Environmental Protection, Bureau of Invasive Plant Management

U.S. Army Engineer Research and Development Center

Gulf States Marine Fisheries Commission, Gulf and South Atlantic Regional Panel

University of Florida, Center for Aquatic and Invasive Plants

Ontario Ministry of Natural Resources

Great Lakes Fishery Commission

U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Mid-Continent Ecology Division-Duluth, Minnesota and Grosse Ile, Michigan

Ontario Power Generation

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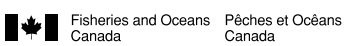

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Frances Lucy, Past Chair, Technical Program Committee, ICAIS 2004, Institute of Technology, Sligo

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Tom Morris, Transport Canada Marine

Charles Jacoby, University of Florida, Department of Fisheries and Aquatic Sciences

William T. Haller, University of Florida, Institute of Food and Agricultural Sciences

Alfred F. Cofrancesco, Jr., U.S. Army Engineer Research & Development Center

Bivan Patnaik, U.S. Coast Guard

Pamela Hall-Thibodeaux, U.S. Fish and Wildlife Service

Sharon Gross, U.S. Geological Survey

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The introduction and spread of invasive species in freshwater and marine environments is a worldwide problem that is increasing in frequency and magnitude. An ever-growing number of aquatic species are being introduced, becoming established, and causing significant damage to receiving ecosystems, and resulting in economic penalties and threatening native biodiversity.

An ever-growing number of aquatic invasive species are causing increasing damage to ecosystems and the economies that depend upon them.

No ecosystem on the planet is impervious to the onslaught of aquatic invasive species. Florida's Everglades National Park, a United Nations World Heritage Site, is one such ecosystem that struggles with large numbers of invaders that are changing the Park's ecosystem and requiring on-going restoration efforts.

In order to protect natural treasures like the Everglades, and other World Heritage Sites, it is essential to have an integrated and harmonized approach involving the full range of stakeholders from resource managers and academics to citizen activists and policy makers. Action must be taken at the local, regional, national and global levels if we are to stem the tide of aquatic invasive species that threaten the biological integrity of unique aquatic habitats.

While several sessions are devoted specifically to the problems in southeast Florida and the Everglades, the 14th International Conference on Aquatic Invasive Species is an opportunity to discuss and document the global impacts of aquatic invasive species. This international forum continues to raise awareness of the necessity for rigorous science in support of policy and decision-making that will lead to the development of effective legislation, with the goal of reducing the impacts of aquatic invasive species not only in Florida, but around the world.

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Ecosystem Management and Restoration: Pushing Back

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Invasive Species in the Southeast United States

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Poster Session

Sunday, May 14, 2006

Sea Grant AIS-HACCP Training Workshop

Preventing the Spread of Aquatic Invasive Species Via Resource Managers, Researchers, and Enforcement Officers

9:00 am
Welcome and course objectives

9:10 am
Why AIS-HACCP?

9:40 am
Pathways of spread

10:30 am
Break (with AIS exhibit)

10:45 am
AIS-HACCP Training Curriculum

12:00
Lunch

12:30 pm
Recap and questions

12:45 pm
AIS-HACCP Plan development by participants

2:15 pm
Participants present plans to group

2:55 pm
Workshop evaluation

3:00 pm
Adjourn

Monday, May 15, 2006

Plenary Session

Session Chair: Sharon Gross, U.S. Geological Survey

8:30
Introductory Remarks
Sue Haseltine, Associate Director for Biology, U.S. Geological Survey, USA
Dr. James Tate, Jr., Science Advisor to the Secretary of the Interior, USA

8:45
Keynote Address
Rock Salt
Director of Everglades Restoration Initiatives, U.S. Department of the Interior, USA

9:00
Knowledge Gaps and Efforts to Address Them
Tim Keeney, Deputy Assistant Secretary of Commerce for Oceans and Atmosphere, NOAA, USA

9:30
Why We Need a National Center for Biological Invasions in the United States
Don C. Schmitz, Florida Department of Environmental Protection, USA

10:00
Break

10:30
Florida's Statewide Strategies for Successful Invasive Aquatic Plant Management
Jeffrey D. Schardt, Florida Department of Environmental Protection, USA

11:00
Everglades Restoration and the Role of Aquatic Exotics
Bob Johnson, Director, South Florida Natural Resources Centre, Everglades National Park, USA

11:30
Questions and Discussion

12:00
Luncheon

The AIS-HACCP approach was adapted from the National Seafood HACCP Alliance for Training and Education by members of the Great Lakes Sea Grant Network through a grant from NOAA to the National Sea Grant College Program. Funding for AIS-HACCP manual revisions and this series of Great Lakes-wide workshops is from the Great Lakes Protection Fund.

Monday, May 15, 2006

Concurrent Session A

Biofouling Mitigation

Session Chair: Gerard van der Velde, Radboud University Nijmegen

1:30
A Retrospective Analysis of Response to the Zebra Mussel in North America
A. Garry Smythe, Shaw Environmental and Infrastructure, USA

1:50
Generation of Life Stage Sensitivity Data to Optimize Chemical Control Strategies
Alan J. Kennedy, Analytical Services, Inc., USA

2:10
Microencapsulated Biobullets for the Control of Biofouling Zebra Mussels
David C. Aldridge, University of Cambridge, UK

2:30
New Industrial Uses of Zebra Mussel Filtration Studies: Density Estimation, Particulate Toxin Development and Bio-inspiration of Water Clarification Techniques
Philine Zu Ermgassen, University of Cambridge, UK

2:50
A Standard for the Control of Zebra Mussels and Quagga Mussels at Ontario Power Generation, Nuclear
Robert A. Hester, Ontario Power Generation, Canada

3:10
Break

3:40
Redesign of the Sodium Hypochlorite Treatment Approach for Zebra Mussels at Niagara Plant Group Hydroelectric Generating Stations
Tony Van Oostrom, Ontario Power Generation, Canada

4:00
The Use of Potassium Chloride to Control Zebra Mussels in an Open Body of Water
Dan Butts, ASI Group Ltd., Canada

4:20
New Technologies for Diverting Introduced and Endemic Fish Species at Industrial Intakes
Paul H. Patrick, Kinectrics Inc., Canada

Concurrent Session B

Invasion Pathways

Session Chair: Geoff Hicks, New Zealand Department of Conservation

1:30
Schools and Science Curricula as Potential Pathways for Aquatic Invasive Species
Samuel S. Chan, Oregon State University, Sea Grant Extension, USA

1:50
Live Food Fish Industry in Canada: Vector and Pathways for Invasive Freshwater Fishes
Becky Cudmore, Fisheries and Oceans Canada, Canada

2:10
Introduction Pathways and Life History Adaptations of Non-native Freshwater Fishes in England
Gordon H. Copp, Centre for Environment, Fisheries and Aquaculture Science (CEFAS), UK

2:30
Off the Beaten Track: Invasion of "Minimally Exposed" Estuaries in the Pacific Northwest
Henry Lee II, U.S. Environmental Protection Agency, USA

2:50
Potentially Invasive Non-native Aquarium Fish and the San Francisco Bay-Delta Region
Judah Grossman, University of California – Davis, USA

3:10
Break

3:40
The Scale of Cryptogenesis in the North Atlantic Ocean
Deniz Haydar, University of Groningen, The Netherlands

4:00
The Invasive Snail *Bithynia tentaculata* (Gastropoda: Prosobranchia) Carries Deadly Parasites for Water Birds in Wisconsin
Jennifer S. Sauer, U.S. Geological Survey, USA

4:20
Secondary Vectors of the Introduced Marine Amphipod *Caprella mutica* on the West Coast of Scotland
Gail Ashton, Dunstaffnage Marine Laboratory, UK

4:20
Monitoring Nonindigenous Species Across the Mediterranean Sea: The Application of Geographic Information System
Franco Andaloro, Central Institute of Research Applied to the Sea (ICRAM), Italy

Concurrent Session C

Ballast Water Policy Progress and Updates: Challenging the World

Session Chair: Bivan Patnaik, United States Coast Guard

1:30
U.S. Coast Guard Aquatic Nuisance Species Program Overview
Richard Everett, U.S. Coast Guard, USA

1:50
Canada's National Regulatory Approach to Ballast Water Management
Tom Morris, Transport Canada Marine, Canada

2:10
Compliance and Enforcement with the Coast Guard's Mandatory Ballast Water Management (BWM) Program
LT Keith Donohue, U.S. Coast Guard, USA

2:30
Canada's Enforcement Regime for New Ballast Water Management Regulations
Christopher J. Wiley, Fisheries and Oceans Canada and Transport Canada, Canada

2:50
U.S. Coast Guard NOBOB Policy: Best Management Practices for NOBOB Vessels Entering the Great Lakes
Bivan R. Patnaik, U.S. Coast Guard, USA

3:10
Break

3:40
U.S. Coast Guard Ninth District Program
CDR Karen Phillips, U.S. Coast Guard, USA

4:00
Ballast Water Best Management Practices for Transoceanic Ships: Theory and Practicability
David F. Reid, National Oceanic and Atmospheric Administration, USA

Tuesday, May 16, 2006

Concurrent Session A

Invasive Bivalves: On the Move

Session Chair: Frances Lucy, Institute of Technology Sligo

8:30
The *Mytilus galloprovincialis* Invasion of South Africa – Threats and Opportunities
Charles Griffiths, University of Cape Town, South Africa

8:50
***Perna viridis* vs. *Perna perna*: Who Will Win the Invasion Race?**
Sanjeevi Rajagopal, Radboud University, The Netherlands

9:10
The Green Mussel, *Perna viridis*, in the Southeast United States
Shirley Baker, University of Florida, USA

9:30
Environmental Changes in Guaíba Lake, Southern Brazil, After the Settling of *Limnoperna fortunei* (Dunker, 1857)
Maria C.D. Mansur, UFMT Mato Grosso, Brazil

10:10
Break

Caulerpa Assessment, Prevention and Management

Session Chair: Don Schmitz, Florida Department of Environmental Protection

10:40
Invasion Impact Persists After Eradication of *Caulerpa racemosa Var. cylindracea*
Judith Klein, Centre d'Océanologie de Marseille, France

11:00
Preventing the Establishment of *Caulerpa taxifolia* in the Gulf of Mexico: Detection of *Caulerpa taxifolia* by DNA Analysis
John Teem, Florida Department of Agriculture and Consumer Services, USA

11:20
Management Planning for the Genus *Caulerpa* in Waters of the United States
Jeffrey Herod, U.S. Fish and Wildlife Service, USA

11:40
***Caulerpa taxifolia*: Education and Outreach to the Aquarium Industry, Inspectors and High School Students**
Susan F. Zaleski, University of Southern California, Sea Grant Program, USA

12:00
Luncheon

Concurrent Session B

Policy and Program Development

Session Chair: Peter Thompson, Fisheries and Oceans Canada

8:30
The Federal Aquatic Nuisance Species Task Force: 15 Years of Evolving
Scott Newsham, Executive Secretary, ANS Task Force, USA

8:50
Aquatic Invasive Species and the Review of the Great Lakes Water Quality Agreement: The Opportunities and Challenges that Lay Ahead
The Rt. Hon. Herb Gray, Chair, Canadian Section, International Joint Commission, Canada

9:10
The Aquatic Invasive Species Action Plan for the Great Lakes: The Results of Regional Collaboration Under President Bush's Executive Order of May 2004
Marc Gaden, Great Lakes Fishery Commission, USA

9:30
Establishment and Operation of a National Center for Biological Invasions in the United States
Marilyn Barrett-O'Leary, Southeast Aquatic Resources Partnership and Louisiana Sea Grant, USA

9:50
Facilitating the Development of an Invasive Species Management Plan for the Commonwealth of Pennsylvania
Sarah Whitney, Pennsylvania Sea Grant, USA

10:10
Break

10:40
Invasive Species Policy: A Need for Action
Sherman Wilhelm, Florida Department of Agriculture and Consumer Services, USA

11:00
National Aquatic Species Risk Analysis: A Call for Improved Implementation
Paul Zajicek, Florida Department of Agriculture and Consumer Services, USA

11:20
The Legal Implications of Mandatory Identification Systems for Aquaculture Operations
Stephanie Showalter, University of Mississippi, USA

11:40
Successful Eradication of *Caulerpa taxifolia* in California Through Rapid Response and Team Approach
Lars W.J. Anderson, U.S. Department of Agriculture, Agricultural Research Service, USA

12:00
Luncheon

Concurrent Session C

Ballast Water: Advances in Science

Session Chair: Richard Everett, United States Coast Guard

8:30
A Molecular Diagnostic Approach to the Detection and Management of Marine Invasive Species From Ballast Water
Julio Harvey, U.S. Geological Survey, USA

8:50
The Transfer of Plankton Species in Coastal Ballast Water
Monaca Noble, Portland State University, USA

9:10
Potential for Introduction of Non-native Marine Species in Select Caribbean Ports Receiving Cruise Ship Traffic and Possible Mitigation With Ballast Exchange
Linda L. Farmer, University of Miami, USA

9:30
Decision Support to Reduce the Risk of Introduction of Aquatic Organisms by Maritime Commerce Into Delaware Bay and Other Port Ecosystems
Joana Tavares, University of Delaware, USA

9:50
Ballast Water Sampling and Options for Rapid Sample Analysis
Stephan Gollasch, Go Consult, Germany

10:10
Break

10:40
In-line Pipe Sampling Methods for Continuous Sampling of Ballast Piping Systems
Stephanie Robbins, Naval Research Laboratory, USA

11:00
Biological In-tank Sampling and Sample Degradation for Standardized Ballast Water Treatment Technology Sampling
Scott Riley, Naval Research Laboratory, USA

11:20
Does Open-ocean Ballast Exchange Prevent Transfer of Invertebrates Between Freshwater Ports?
Derek Gray, University of Windsor, Great Lakes Institute for Environmental Research, Canada

11:40
Individual and Combined Effects of Sonication and Advanced Chemical Oxidants as Mechanisms to Eradicate Various Life History Stages of a Model Aquatic Macroinvertebrate Under Static And Continuous Flow Regimes
Meghana Gavand, University of Alabama at Birmingham, USA

12:00
Luncheon

Tuesday, May 16, 2006

Concurrent Session A

Alien Fish or Catch of the Day?

Session Chair: Doran Mason, National Oceanic and Atmospheric Administration

1:30
Some Biological Consequences of a Nonindigenous Forage Fish on Lake Trout and Other Salmonids Populations in the Great Lakes Basin
Dale C. Honeyfield, U.S. Geological Survey, USA

1:50
Do Aquaculture Released Fish Exhibit the Same Life History Patterns in Non-native Environments as They Do at Home? A Case Study of Nile Tilapia, *Oreochromis niloticus*
Mark S. Peterson, University of Southern Mississippi, USA

2:10
Invasion Genetics of Ponto-Caspian Gobies in the Great Lakes and Beyond: Comparisons With Native Populations and Relatives
Carol A. Stepien, University of Toledo, USA

2:30
Invasive Gobies in the Middle Danube: What Impact?
Vladimír Kovác, Comenius University, Slovakia

2:50
Present Status of the North American Fish Species, Fathead Minnow *Pimephales promelas* in Flanders, Belgium
Hugo Verreycken, Institute for Forestry and Game Management, Belgium

3:10
Break

Concurrent Session B

Monitoring, Detection and Response

Session Chair: Alfred F. Cofrancesco, U.S. Army Engineer Research and Development Center

1:30
Non-native Freshwater Plants in Ireland
Joe Caffrey, Central Fisheries Board, Ireland

1:50
Rapid Response Planning Efforts for Aquatic Invaders in Massachusetts
Susan Park, Massachusetts Office of Coastal Zone Management, USA

2:10
Ready, Set, Go – Applying Spill Response Lessons to AIS Rapid Response Planning
Paul Heimowitz, U.S. Fish and Wildlife Service, USA

2:30
Keeping a Regular Watch For Marine Pests: A Quality-assured Monitoring Program for Australia and New Zealand
Jemma Martin, Department of Agriculture, Fisheries and Forestry, Australia

2:50
Ontario's Response to Detection of Round Goby (*Neogobius melanostomus*) in a Tributary of Lake Simcoe: An Eradication Case Study
Jason Borwick, Ontario Ministry of Natural Resources, Canada

3:10
Break

Concurrent Session C

Ballast Water: Advances in Control Technologies

Session Chair: Christopher J. Wiley, Fisheries and Oceans Canada and Transport Canada

1:30
Design and Implementation of Shipboard Tests of Ballast Water Treatment: The Case of Venturi Oxygen Stripping (VOS)
George Smith, Smithsonian Environmental Research Center, USA

1:50
Performance Monitoring of a Biological Deoxygenation Process to Treat Ballast Water
Eloïse Veilleux, University of Sherbrooke, Canada

2:10
Treatment of Ballast Water Organisms Using High-power Ultrasound
Eric R. Holm, Naval Surface Warfare Center - Carderock Division, USA

2:30
Tests of a Ballast Water Treatment System Onboard an Ocean-going Vessel: The OceanSaver Approach
Stephan Gollasch, GoConsult, Germany

2:50
M.V. *Federal Welland* / OceanSaver Ballast Water Treatment Project
Georges H. Robichon, Fednav Limited, Canada

3:10
Break

Concurrent Session A

Alien Fish or Catch of the Day?

Session Chair: Charles Jacoby, University of Florida

3:40
Impact of Exotic Fish Species on Native Freshwater Fish Biodiversity of Pakistan
Abdul Majid Khan, University of the Punjab, Pakistan

4:00
Silver Carp (*Hypophthalmichthys molitrix*) and the Bighead Carp (*H. nobilis*) in the Mississippi River Basin: Occurrence Data and Dispersal Patterns
Martin T. O'Connell, University of New Orleans, USA

4:20
An Emergent Infectious Disease Threatens European Fish Biodiversity
Rodolphe E. Gozlan, Centre for Ecology and Hydrology, UK

4:40
Habitat Quality of Invasive Nile Tilapia (*Oreochromis niloticus*), Reproductive Behavior, and Interactions With Native Centrarchid Species in Coastal Mississippi
Jennifer L. McDonald, University of Southern Mississippi, USA

5:00
Diet Overlap Between Alien Fish Species, Nile Tilapia (*Oreochromis niloticus*), and Native Cyprinid Fish Species (Family Cyprinidae) in Natural Aquatic Environments in Thailand
Wansuk Senanan, Burapha University, Thailand

5:20
Exotic Fish Species and Changes in Catch Composition of the Ciénaga Grande de Santa Marta Estuarine System, Northern Colombia
Jenny Leal-Flórez, University of Bremen – Center for Marine Tropical Ecology, Germany

Concurrent Session B

Apple Snail Ecology, Impacts and Management

Session Chair: Scott Hardin, Florida Fish and Wildlife Commission

3:40
Managing the Invasive Alien Molluscs, *Pomacea* spp.: A Global Perspective
Ravindra C. Joshi, Philippine Rice Research Institute, Philippines

4:00
Applesnail (*Pomacea canaliculata*-complex): Distribution, Density, Population Dynamics in Southeastern Texas and Potential Threat to the Rice Industry and Coastal Ecosystems
Lyubov E. Burlakova, Stephen F. Austin State University, USA

4:20
Applesnail (*Pomacea canaliculata*-complex): Distribution, Projected Spread and Population Dynamics on the Texas Gulf Coast
David N. Hollas, Stephen F. Austin State University, USA

4:40
Applesnail (*Pomacea canaliculata*-complex): Feeding Selectivity, Reproductive Potential and Environmental Impact on Southeastern Texas Ecosystems
Leah D. Cartwright, Stephen F. Austin State University, USA

5:00
Feeding Preference and Consumption Rates of Aquatic Vegetation by the Channeled Apple Snail
William T. Haller, University of Florida Center for Aquatic and Invasive Plants, USA

5:20
Genetic Characterization of Invasive Apple Snail Populations in the Continental United States
Timothy M. Collins, Florida International University, USA

5:40
The Tale of Two Snails: Comparing and Contrasting the Ecological Roles of a Natural Versus Exotic Population of Pomacea
Romi L. Burks, Department of Biology, Southwestern University, USA

Concurrent Session C

Ballast Water: Advances in Control Technologies

Session Chair: Irene Brooks, International Joint Commission

3:40
Effectiveness and Toxicological Impact of Two Ballast Water Treatment Methods at Very Cold Water Conditions
Yves de Lafontaine, Environment Canada, Canada

4:00
Carbon Dioxide as a Biocide for Ship Ballast Water: Some Experimental Results
Steve Bollens, University of California, USA

4:20
Two Shipboard Demonstrations of Chlorine Dioxide to Control AIS: Swedish Flagged Ro-Ro/Container and U.S. Flagged ITB Bulker
Tom Perlich, Echochlor Inc., USA

5:00
Effectiveness and Kinetics of Ferrate as a Disinfectant for Ballast Water
Andrea Jessen, University of Central Florida, USA

5:20
Ballast Water Treatment Using Crumb Rubber Filtration: Effects of Coagulation and Salinity
Yuefeng Xie, Penn State Harrisburg, USA

5:40
Incursion Response: Development and Testing of Tools for Use in the Marine Environment
Dan McClary, Kingett Mitchell Ltd., New Zealand

6:00
Proof of Principle Evaluation of an Innovative, Sparker-based Ballast Water Treatment Methodology
Renata Claudi, RNT Consulting Inc., Canada

Wednesday, May 17, 2006

Concurrent Session A

Dreissena

Session Chair: Abraham bij de Vaate, Waterfauna Hydrobiologisch Adviesbureau

8:30
Zebra Mussel Grazing Impact on Phytoplankton Community Composition of Lake Erken, Sweden
Rahmat Naddafi, Uppsala University, Sweden

8:50
Mitigation of Dreissenid (Zebra and Quagga) Mussel Mortality on Native Unionids: A Place to Survive
Don W. Schloesser, U.S. Geological Survey, USA

9:10
***Dreissena polymorpha* in Belarus: 200 Years of Invasion, 70 Years of Research**
Alexander Y. Karatayev, Stephen F. Austin State University, USA

9:30
Early Life Stages of Zebra Mussels: The Importance of Long-term Datasets in Invasion Ecology
Frances Lucy, Institute of Technology, Sligo, Ireland

9:50
Dispersal Pathways of *Dreissena polymorpha*: Results of PCR Based ALFP-fingerprinting
Sanjeevi Rajagopal, Radboud University, The Netherlands

10:10
Break

10:40
Eukaryotic Mantle-Cavity Symbionts of *Dreissena polymorpha* in Spain, Ireland, France, England and Poland
David Bruce Conn, Berry College, USA

11:00
Predators, Endosymbionts and Benthic Competitors of Zebra Mussels: Interactions and Impacts
Daniel P. Molloy, New York State Museum, USA

11:20
Accumulation of Human Waterborne Parasites by Zebra Mussels (*Dreissena polymorpha*) and Asian Freshwater Clams (*Corbicula fluminea*)
Thaddeus Graczyk, Johns Hopkins Bloomberg School of Public Health, USA

11:40
Oklahoma Zebra Mussel (*Dreissena polymorpha*) Distribution With a Focus on Densities, Settling and Growth in Lake Oologah, Oklahoma
Chad J. Boeckman, Oklahoma State University, USA

12:00
Luncheon

Concurrent Session B

Economic Impacts

Session Chair: Allen Olson, International Joint Commission

8:30
Estimating the Economic Impacts of Aquatic Invasive Species
Sabrina Lovell, U.S. Environmental Protection Agency, USA

8:50
Estimating the Economic Impact of Zebra Mussels Within Their North American Range, 1989-2004
Nancy A. Connelly, Cornell University, USA

9:10
Introduction of the Carp *Cyprinus carpio* Into Lake Naivasha, Kenya: Economic Savior or Ecological Disaster?
J. Robert Britton, Environment Agency, UK

9:30
Household Welfare Impacts of the Water Hyacinth (*Eichhornia crassipes*) in the Kenyan Side of Lake Victoria
Stephen K. Mailu, Lake Victoria Environmental Management Project, Kenya

9:50
Assessing Risk Associated With Exotic Species: An Aquaculture Perspective
John Teem, Florida Department of Agriculture and Consumer Services, USA

10:10
Break

10:40
Exotic Aquatic Species Introductions in the Philippines for Aquaculture – A Threat to Biodiversity or a Boon to the Economy?
Arsenia G. Cagauan, Central Luzon State University, Philippines

11:00
Biological Invasion Control and Ecosystem Disturbance: A Bio-economic Analysis of the Bay of Brest Scallop Fishery, France
Marjolaine Frésard, Université de Bretagne Occidentale, France

11:20
The Prevalence of Taura Syndrome Virus, White Spot Syndrome Virus and Yellow Head Virus in Wild Shrimp Species in Thailand
Praparsiri Barnette, Burapha University, Thailand

12:00
Luncheon

Concurrent Session C

Ship Fouling: Another Vector

Session Chair: LT Keith Donohue, United States Coast Guard

8:30
Can the Spread of Invasive Species by Hull Fouling be Controlled?
Martin H. Davis, Fawley Biofouling Services, UK

8:50
Biofouling as a Vector for the Introduction of Nonindigenous Marine Species to New Zealand: Evaluation of Risks from Recreational Yachts
Oliver Floerl, National Institute of Water and Atmospheric Research, New Zealand

9:10
***En route* Survivorship of Biofouling Organisms on Various Vessel Types**
Ashley D.M. Coutts, Cawthron Institute, New Zealand

9:30
Ships' Sea Chests: An Overlooked Mechanism for Species Transfers
Ashley D.M. Coutts, Cawthron Institute, New Zealand

9:50
Patterns and Invasion Risk of Hull Fouling on the U.S. Pacific Coast
Ian Davidson, Portland State University, USA

10:10
Break

10:40
Mobile vs. Sessile Organisms in Ship Hull Fouling; Results from a German Shipping Study
Stephan Gollasch, GoConsult, Germany

12:00
Luncheon

Concurrent Session A

Education and Outreach: Public Information Pathway

Session Chair: Robert Gourd, International Joint Commission

1:30
Habitattitude™ Baseline Survey Shows that Aquarists and Water Gardeners Can Be the Problem and Solution to AIS Spread
Douglas A. Jensen, University of Minnesota Sea Grant Program, USA

1:50
Social Marketing – Helping to Address the Aquatic Invasive Species Problem
Joe Starinchak, U.S. Fish and Wildlife Service and National ANS Task Force, USA

2:10
Public Awareness and Rapid Response Planning: Michigan's Experience with Heading Off Hydrilla
Carol Swinehart, Michigan Sea Grant, USA

2:30
In the Classrooms and in the Parks: New Outreach Programs About Florida's Invasive Plants Crisis, for Science Teachers and State Park Workers
Amy Richard, University of Florida, Center for Aquatic and Invasive Plants, USA

2:50
Empowering Teachers with Knowledge and Skills on Invasive and Exotic Species: A Teacher Workshop
Marella Crane, University of Florida, Sea Grant Extension Program, USA

3:10
Break

Concurrent Session B

Invasion Dynamics

Session Chair: David F. Reid, National Oceanic and Atmospheric Administration

1:30
Effects of the Louisiana Crayfish Invasion on the African Clawless Otter in the Ewaso Ng'iro River Ecosystem
Mordecai O. Ogada, Kenyatta University, Kenya

1:50
"Inconspicuous" Impacts of Nonindigenous Species in a Pacific Northwest Estuary
Blake E. Feist, National Oceanic and Atmospheric Administration, USA

2:10
Risk Assessment of Round Goby on Lake Trout Restoration in the Great Lakes and the Need for Mitigation
John D. Fitzsimons, Fisheries and Oceans Canada, Canada

2:30
Winners and Losers – Do Life History Traits Promote Gammarid Invasions in Europe?
Michal Grabowski, University of Lodz, Poland

2:50
Invasions as Dynamic Processes Determined by Seasonal Influences: A Study on the Invasion of the Rhine by *Dikerogammarus villosus*
Gerard van der Velde, Radboud University Nijmegen, The Netherlands

3:10
Break

Concurrent Session C

Ship Fouling: Another Vector

Session Chair: LT Heather St. Pierre, United States Coast Guard

1:30
The Development of Management Recommendations for Merchant Vessel Fouling in California
Lynn Takata, California State Lands Commission, USA

1:50
Marine Pests Left High and Dry — New Australian Measures for Biofouling on Yachts
Robert Langlands, Department of Agriculture, Fisheries and Forestry, Australia

2:10
Recreational Boating Patterns, A Useful Approach to Risk-rank Sub-regions Around Golden-Tasman Bay Region, New Zealand
Hernando Acosta, Cawthron Institute, New Zealand

2:30
An Epidemiological Model for Simulating the Spread of Introduced Marine Species by Vessel Movements and Comparing the Efficacy of Management Options
Oliver Floerl, National Institute of Water and Atmospheric Research, New Zealand

3:10
Break

Wednesday, May 17, 2006

Concurrent Session A

Education and Outreach: Public Information Pathway

Session Chair: Herb Gray, International Joint Commission

3:40
The Student Conservation Association Invasive Species Project and the National Park Service – A Partnership for the Future
Phillip L. Clark, Student Conservation Association, USA

4:00
The National Aquatic Nuisance Species Clearinghouse
Charles R. O'Neill, Jr., New York Sea Grant and National Aquatic Nuisance Species Clearinghouse, USA

4:20
Clean Boats, Clean Waters – A Fighting Chance!
Laura Felda-Marquardt, University of Wisconsin, USA

Concurrent Session B

Invasion Dynamics

Session Chair: Dennis Schornack, International Joint Commission

3:40
Xenodiversity of the Baltic Sea: Origin, Spread and Impacts
Sergej Olenin, Klaipeda University, Lithuania

4:00
Baseline Port Surveys for Invasive Marine Species in the South Atlantic Bight
Marcy Ann Mitchell, University of Georgia, USA

4:20
Ecosystem-level Consequences of *Spartina* Invasion in West Coast Estuaries
Edwin D. Grosholz, University of California – Davis, USA

4:40
Introduced Pumpkinseed Sunfish (*Lepomis gibbosus*) Ruins Moorland Pool Restoration Projects
Hans Esselink, Radboud University Nijmegen, The Netherlands

5:00
Dominance of the Invasive Invertebrates in the Littoral Zone of Lake Balaton (Hungary)
Ilona B. Muskó, Balaton Limnological Research Institute of the Hungarian Acadamy of Sciences, Hungary

5:20
A National Incursion Response to the Invasive Diatom, *Didymosphenia geminata*, in New Zealand Freshwaters
Christina C. Vieglais, Biosecurity New Zealand, New Zealand

Concurrent Session C

Ballast Water Treatment Systems Evaluation

Session Chair: Ron Jackson, United States Coast Guard

3:40
Standardized Ballast Water Treatment Test Facility Development – General Overview of the Technical Challenges and Needs
Edward J. Lemieux, Naval Research Laboratory, USA

4:00
Validation of Methods for the Injection of Surrogate Organisms Into Ballast Piping
Edward J. Lemieux, Naval Research Laboratory, USA

4:40
Surrogate Population Kinetics in Ballast Water Tanks Applied to the Technology Treatment Testing
Stephanie Robbins, Naval Research Laboratory, USA

5:00
Inorganic and Organic Content Augmentation for Controlled Water Quality Testing of Ballast Water Treatment Systems
Edward J. Lemieux, Naval Research Laboratory, USA

5:20
Analytical Tools Development for the Enumeration and Viability Determination of Aquatic Organisms
Bruce Nelson, Naval Research Laboratory, USA

5:40
Filter Train Performance Testing – Results of 100 Operational Hours
Scott Riley, Naval Research Laboratory, USA

Concurrent Session A

Predictive Risk Assessment

Session Chair: Dorn Carlson, National Oceanic and Atmospheric Administration

8:30
Risk Assessment of Snakeheads (Channidae) in Canada
Nicholas E. Mandrak, Fisheries and Oceans Canada, Canada

8:50
To Stock or Not to Stock: Managing the Risk of AIS Introductions by Fish Hatcheries
Paul Heimowitz, U.S. Fish and Wildlife Service, USA

9:10
Development of an Ecosystem Model for Investigation of Ecological Impacts of Aquatic Invasive Species in Lake Michigan
David H. Miller, U.S. Environmental Protection Agency, USA

9:30
Predicting the Characteristics of Aquatic Invertebrate Invaders
Dianna K. Padilla, Stony Brook University, USA

9:50
A Quantitative Risk Framework for the Assessment of Aquatic Invasive Species
Marten A. Koops, Fisheries and Oceans Canada, Canada

10:10
Break

10:40
A Molecular Ecological Approach to Determining the Distribution, Establishment and Impacts of Invasive Species in Marine Ecosystems
Rusty Rodriguez, U.S. Geological Survey, USA

11:00
Identification of Specific Water Bodies at Risk for Zebra Mussel Invasion Using Boater Surveys Conducted by 100th Meridian Initiative
David Britton, University of Texas at Arlington, USA

11:20
Ecological Plasticity of Invasive Aquatic Species: A Confounding Factor for Risk Assessments
Duane Chapman, U.S. Geological Survey, USA

12:00
Luncheon

Concurrent Session B

Invasive Species in the Southeast United States

Session Chair: Ron Lukens, Gulf States Marine Fisheries Commission

8:30
Monitoring Fish Invasions and Their Impacts in Southern Florida
Joel C. Trexler, Florida International University, USA

8:50
Nonindigenous Fish Establishment in the Central Everglades Marsh
Mac Kobza, South Florida Water Management District, USA

9:10
Assessing the Potential Impact of African Jewelfish [(*Hemichromis letourneuxi*) (Cichlidae)] in Everglades Marshes: Prey Selectivity and Anti-predator Response by Naïve Prey
Jennifer S. Rehage, U.S. Geological Survey, USA

9:30
Relative Impact of Nonindigenous African Jewelfish [(*Hemichromis letourneuxi*) (Cichlidae)] on Native Everglades Fishes in Subterranean Dry-season Refuges
Shawn E. Liston, U.S. Geological Survey, USA

9:50
Disposable Pets, Unwanted Giants: Pythons in Everglades National Park
Ray W. "Skip" Snow, Everglades National Park, USA

10:10
Break

10:40
A Programmatic Overview of the Florida Fish and Wildlife Conservation Commission's Efforts to Prevent, Assess, and Manage Exotic Freshwater Fishes
Paul Shafland, Florida Fish and Wildlife Conservation Commission, USA

11:00
Genetic Analysis of the Diversity, Origins and Pathways of Introduction of Nonindigenous Swamp Eels (Synbranchidae) in the United States
Matthew F. Osentoski, Florida International University, USA

11:20
Diet of the Nonindigenous Asian Swamp Eel *Monopterus albus* (Synbranchidae) in Tropical Ornamental Aquaculture Ponds in West Central Florida
Jeffrey E. Hill, University of Florida, USA

12:00
Luncheon

Concurrent Session C

Ecosystem Management and Restoration: Pushing Back

Session Chair: John Dettmers, Great Lakes Fishery Commission

8:30
The National Park Service – Building a Comprehensive Response to Invasive Species
Linda Drees, National Park Service, USA

8:50
Building an Aquatic Invasive Species (AIS) Response Through Partnership and Collaboration
Sara Pelleteri, Hawaii Department of Land and Natural Resources, USA

9:10
Cultures in Conflict: The Complexities of Invasive Species Management
Wei Ying Wong, Brown University, Center for Environmental Studies, USA

9:30
Geographical Eradication of an Alien Octocoral, *Carijoa riisei*, in Hawaii
Anthony Montgomery, Department of Land and Natural Resources, USA

9:50
Impact of the Invasive Crayfish, *Procambarus clarkii*, in the Mediterranean Wetlands and Proposals for its Mitigation
Francesca Gherardi, Università di Firenze, Italy

10:10
Break

10:40
Invasive, Predatory Fish Removal in a Large Desert River: Feel Good or Effective Project, Verde River, Arizona, USA
John R. Rinne, Rocky Mountain Research Station, USA

11:00
Home vs. Guests – The Game is on Against Aliens
Kathleen Beyer, Centre for Ecology and Hydrology, UK

11:20
Case Studies on the Eradication of the Invasive Cyprinid Topmouth Gudgeon *Pseudorasbora parva* from Fisheries in England
J. Robert Britton, Environment Agency, UK

11:40
Directed Extinction of Exotic Fish Populations in the Wild Using a Fish Bearing Multiple Y Chromosomes
John Teem, Florida Department of Agriculture and Consumer Services, USA

12:00
Luncheon

Thursday, May 18, 2005

Concurrent Session A

Lionfish: King of the Aquatic Jungle

Session Chair: Dean Wilkinson, National Oceanic and Atmospheric Administration

1:30
The Rapid Establishment of the Indo-Pacific Lionfish, *Pterois volitans/miles* complex, in the Western North Atlantic
Paula E. Whitfield, National Oceanic and Atmospheric Administration, USA

1:50
Genetic Analyses of the Western Atlantic Lionfish Invasion
D. Wilson Freshwater, Center for Marine Science, University of North Carolina Wilmington, USA

2:10
Reproductive Biology and Invasiveness of the Lionfish, *Pterois volitans*, in the Western Atlantic, USA
James Adiel Morris, Jr., National Oceanic and Atmospheric Administration, USA

2:30
Age and Growth of Lionfish, *Pterois volitans*, Inhabiting the Offshore Waters of Onslow Bay, North Carolina, USA
Jennifer C. Potts, National Oceanic and Atmospheric Administration, USA

2:50
Predatory Impacts of the Indo-Pacific Lionfish in the Atlantic Waters of the Southeast United States
Roldan C. Muñoz, National Oceanic and Atmospheric Administration, USA

3:10
Break

3:40
Parasites of the Invasive Red Lionfish, *Pterois volitans*, Off the North Carolina Coast, USA
Ann M. Barse, Salisbury University, USA

Concurrent Session B

Invasive Species in the Southeast United States

Session Chair: Pam Fuller, U.S. Geological Survey

1:30
Implications for Controlling Bighead Carp From Stock-recruit Modeling of Population Dynamics in the Illinois and Mississippi Rivers
Michael Hoff, U.S. Fish and Wildlife Service, USA

1:50
Meeting New Challenges in Hydrilla (*Hydrilla verticillata*) Management in Florida
Michael D. Netherland, U.S. Army Corps of Engineers, USA

2:10
Managing Invasive Species Through Partnership for Healthy Coastal Ecosystems
Marilyn Barrett-O'Leary, Louisiana Sea Grant, USA

2:30
Invasive Species Initiatives in the Galveston Bay Estuary: Risk Assessment, Research, Management and Outreach
Lisa A. Gonzalez, Houston Advanced Research Center, USA

2:50
A Test of the Impact of Hydrilla Introduction on Biodiversity in Florida Lakes
Melissa Woods Jackson, University of Florida, USA

3:10
Break

3:40
Invasion of *Melaleuca quinquenervia* Alters Soil Microbial Population Dynamics
Melissa R. Martin, University of Florida, USA

4:00
Limitation of Giant Salvinia (*Salvinia molesta* Mitchell) by Nutrients and pH
John D. Madsen, Mississippi State University, USA

Concurrent Session C

Ecosystem Management and Restoration: Pushing Back

Session Chair: Tony Pernas, National Park Service

1:30
There Are No Hopeless Cases: Mitigating the Impact of Invasive Freshwater Fishes in the Cape Floristic Region, South Africa
Sean Marr, University of Cape Town, South Africa

1:50
Nonindigenous Species of the Pacific Northwest: An Overlooked Risk?
Beth L. Sanderson, National Oceanic and Atmospheric Administration, Fisheries, USA

2:10
The Invasion of Giant Salvinia in the United States and its Suppression Using Classical Biological Control
Philip W. Tipping, U.S. Department of Agriculture, USA

2:30
Potential Biological Control of West Indian Marsh Grass (*Hymenachne amplexicaulis*) in Florida
Rodrigo Diaz, University of Florida, USA

2:50
The Impacts and Management of Torpedograss (*Panicum repens*) in the Marsh of Lake Okeechobee, Florida
Mike Bodle, South Florida Water Management District, USA

3:10
Break

3:40
New Herbicidal Tools for Integrated Management of Aquatic Invasive Plants
Mark A. Heilman, SePRO Corporation, USA

4:00
Effectiveness of Product LSP™ in the Growth Inhibition of the Duckweed (*Lemna* sp.) of Maracaibo Lake, Venezuela
William Jimenez C., Globalquimica de Venezuela C.A., Venezuela

Southeast U.S. sessions sponsored by Gulf States Marine Fisheries Commission/Gulf and South Atlantic Regional Panel on ANS

Poster Session

Investigation on the Status and Impact of Jaguar Guapote in Taal Lake, Philippines
Edna V. Agasen, Republic of the Philippines Department of Agriculture, Philippines

The IR-4 Project: New Opportunity – Aquatic Herbicide Registration
Marija Arsenovic, Rutgers University, USA

Invasion at a Snail's Pace: *Pomacea canaliculata* and Everglades National Park
Danielle E. Bamford, Everglades National Park, USA

Use of Long-term Monitoring Data to Evaluate Potential Impacts of Asian Carp on Native Filter-feeding Fishes in the Upper Mississippi River System
Valerie A. Barko, Missouri Department of Conservation, USA

Bozeman Fish Technology Center - Aquatic Nuisance Species and Aquatic Animal Health Program
Linda Beck, U.S. Fish and Wildlife Service, Bozeman Fish Technology Center, USA

A Potential Role for Alien Sunbleak *Leucaspius delineatus* in the Further Dissemination of a Non-native Parasite
Kathleen Beyer, Centre for Ecology and Hydrology, UK

Impact of Invasive Grasses on Crop Production in Guyana
Dyndial P. Bishundial, Guyana Sugar Corporation Inc., Guyana

***Mytella charruana* Along the Atlantic Coast of Florida: A Successful Invasion?**
Michelle Boudreaux, University of Central Florida, USA

Managing Natural Resource Pathways With HACCP: Planning is Everything
David K. Britton, U.S. Fish and Wildlife Service, USA

Where Did They Come From and Where Are They Going? Genetic Analysis of Sources and Sinks for the Round Goby and Zebra Mussel
Joshua E. Brown, University of Toledo, USA

A Method for Distinguishing Dark False Mussels from Zebra Mussels
John F. Christmas, Jr., Franklin Environmental Group Ltd., USA

Navigational Buoy Survey of Invasive and Native Benthic Invertebrates of the Lower Great Lakes and St. Lawrence River
David Bruce Conn, Berry College, USA

Fatty Acid Composition of the Invasive Caprellid, *Caprella mutica* (Crustacea: Amphipoda) on the West Coast of Scotland: Trophic and Environmental Implications
Elizabeth J. Cook, Dunstaffnage Marine Laboratory, UK

Don't Release Aquatic Invasive Species Into the San Francisco Bay/Sacramento-San Joaquin River Delta: A RIDNIS Project Outreach Poster
Holly A. Crosson, University of California, USA

Development of DNA-based Tools for Identification and Monitoring of Aquatic Introduced Species
John A. Darling, U.S. Environmental Protection Agency, USA

Chinese Mitten Crab (*Eriocheir sinensis*) in the St. Lawrence River (Canada): New Records and Risk of Invasion
Yves de Lafontaine, Environment Canada, Canada

The Limnological Characteristics of Aquatic Environments Which Support the Golden Mussel (*Limnoperna fortunei*, Dunker, 1857) and the Potential of the Golden Mussel to Further Spread Within the Paraguay River Basin, Brazil
Márcia Divina de Oliveira, Embrapa Pantanal, Brazil

Dispersal, Recruitment, and Survival of the Exotic Brazilian Pepper in a Florida Estuary
Melinda Donnelly, University of Central Florida, USA

The National Park Service Exotic Plant Management Teams (EPMTs) Free-standing Display
Linda Drees, National Park Service, USA

Bioinvasions in Nearshore Restoration Projects: How Can Policy and Management of Invasions Be Most Effective?
Phebe Drinker, University of Washington, USA

Solution Holes in the Rocky Glades Region of Everglades National Park: Sources or Sinks of Nonindigenous Fishes?
Bradley E. Dunker, U.S. Geological Survey, USA

Nonindigenous Fishes in Sub-tropical Wetlands: Impact of Wetland Restoration on Community Structure, Abundance and Diversity
Kristine J. Dunker, U.S. Geological Survey, USA

The Adaptive Life History of an Invasive, Euryhaline Hydroid, *Cordylophora caspia*
Nadine C. Folino-Rorem, Wheaton College, USA

Potential Harmful Algae in Tampa Bay (USA), Ballast Water Investigations Using a Dinoflagellate Cyst Model
Matt Garrett, Florida Fish and Wilflife Conservation Commission, USA

Effectiveness of Ferrate (FeO_4^{-2}) as a Ballast Water Disinfectant
Nancy Gillis, University of Central Florida, USA

The Impact of Invasive Plant Species on Biodiversity. The Significance of the Soil Seed Bank
Margherita Gioria, University College Dublin, Ireland

Diet Composition and Daily Feeding Activity of the Monkey Goby (*Neogobius fluviatilis*)
Joanna Grabowska, University of Lodz, Poland

Invasive Anthropods and the Diet of European Perch (*Perca fluviatilis*)
Michal Grabowski, University of Lodz, Poland

Ship Ballast Water Studies at Carderock Division Naval Surface Warfare Center
Stephan Verosto and Eric Holm, Naval Surface Warfare Center Carderock Division, USA

The Potential for Spread of *Lygodium microphyllum* Spores by Herbicide Applicators
Jeffrey T. Hutchison, University of Florida, USA

The Development of Regulation Zones as a Tool to Improve Management of Invasive Alien Freshwater Fishes in the Cape Floristic Region, South Africa
N. Dean Impson, Scientific Services, Cape Nature, South Africa

Cichlids in Florida: Nonindigenous Fishes Invading a Changing Landscape
Howard L. Jelks, U.S. Geological Survey, USA

Global Information Databases on Golden Apple Snail at Your Fingertips
Elaine E. Joshi, Philippine Rice Research Institute, Philippines

Developing and Implementing Effective Management Plans and Programs
Champika S. Kariyawasam, Ministry of Environment and Natural Resources, Sri Lanka

Assessing the Spread of Zebra Mussels in the St. Croix River Using Density Measurements and Native Mussels
Byron N. Karns, National Park Service, St. Croix National Scenic Riverway, USA

Early Detection, Status, and Trends Monitoring of Introduced Fishes in Everglades National Park
Jeffrey L. Kline, Everglades National Park, USA

A Risk Assessment of the Clubbed Tunicate *Styela clava* in New Zealand
Daniel Kluza, Biosecurity New Zealand, Ministry of Agriculture and Forestry, New Zealand

Physiological Ecology of the Chlorophyte *Caulerpa brachypus*, an Invader of Deep Coral Reef Habitats Off Southeast Florida
Brian E. Lapointe, Harbor Branch Oceanographic Institution, USA

Detection of Apoptotic Cells to Evaluate Chemical Control Strategies in Early Life Stages
John W. Lynn, Louisiana State University, USA

The Invasion of South America by the Golden Mussel *Limnoperna fortunei* (Dunker, 1857): Population Densities in Natural and Artificial Environments
Maria C.D. Mansur, UFMT Mato Grosso, Brazil

Eco-parasitological Consequences of *Dreissena polymorpha* Spread: A Program for Future Studies
Sergey E. Mastitsky, Belarussian State University, Belarus

Hitchhikers Delight: Five Star Translocation of Nonindigenous Marine Species by Cruise Ships
Dan McClary, Kingett Mitchell Ltd., New Zealand

Impact of the Zebra Mussel *Dreissena polymorpha* on the Ecological Integrity of Lough Sheelin
Michael Millane, University College Dublin, Ireland

Further Evidence of the Environmental Safety of the Zebra Mussel Control Agent *Pseudomonas fluorescens* Strain CL145A: Lack of Acute Toxicity to *Daphnia magna*
Daniel P. Molloy, New York State Museum, USA

The Black Carp (*Mylopharyngodon piceus*) in North America: Probable Establishment and Potential Ecological Impacts
Leo G. Nico, U.S. Geological Survey, USA

The National Aquatic Nuisance Species Clearinghouse and Searchable Database of Holdings
Diane J. Oleson, National Aquatic Nuisance Species Clearinghouse, USA

Sensitivity of Aquatic Invertebrate Resting Eggs to Proposed Chemical and Physical Ballast Tank Treatment Methods
David F. Raikow, National Oceanic and Atmospheric Administration, USA

Alien Fishes in Iberian Freshwater Ecosystems: A Recent Review
Filipe Ribeiro, Faculty of Sciences of University of Lisboa, Portugal

Black Bullhead in a New Reservoir: An Invader Waiting for a Chance to Break Through?
Filipe Ribeiro, Faculty of Sciences of University of Lisboa, Portugal

Ballast Water as an Accidental Vector for the Introduction of Harmful Microalgae Into Tampa Bay, Florida (USA): A Project Overview
Bill Richardson, Florida Fish and Wildlife Conservation Commission, USA

Invasive Species in a Desert River: Impacts on Southwestern USA Native Fishes and Plants
John N. Rinne, Rocky Mountain Research Station USA

Potential for Control of Nonindigenous Asian Swamp Eels (Family Synbranchidae) with Rotenone
Pamela J. Schofield, U.S. Geological Survey, USA

Phytochemicals: An Environmentally Friendly Alternative to Toxic Anti-fouling Coatings
Guy Seabrook, Magellan Companies, Inc., USA

Limpograss Invasion in the Kissimmee River Floodplain
Brent A. Sellers, University of Florida, USA

Biological Test of Plankton By *in situ* Adaptability and Ballast Water Treatment System
Kyoungsoon Shin, KORDI, Korea

Space Invaders: Resistance is Futile, So Hide in the Long Grass
Richard Shucksmith, Dunstaffnage Marine Laboratory, Scotland

Ballast Water Disinfection Using High-power Ultrasonic (HPU) Cavitation Driven by TERFENOL-D
Jon Snodgrass, Etrema Products, Inc., USA

U.S. Coast Guard Aquatic Nuisance Species Outreach Program
Heather J. St. Pierre, U.S. Coast Guard, USA

e-Management for Unwanted Guests: Ontario's Information Management Tools for Invading Species
Christine Villegas, Ontario Ministry of Natural Resources, Canada

Knowledge Gaps and Efforts to Address Them

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One year ago, I summarized the progress that had been made on aquatic invasive species issues. From a policy perspective, there are areas of strength and areas of weakness in both our knowledge and our responses. In general terms, much of our effort has gone toward documenting ecological impacts and the biology of individual species, and we have made much less progress in methods of controlling and managing such species. From the viewpoint of one who has to make decisions when we face limitations on resources, there are few studies or models of economic costs that can be used in conjunction with information on ecological impacts to either determine relative costs and benefits or to establish priorities. Over time, our disciplines have come to agree on a series of functional categories, e.g., prevention, monitoring, early detection and rapid response, and management and control. Identification of strengths and weaknesses in each of these areas may help determine priorities for future activities.

Why We Need a National Center for Biological Invasions in the United States

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The past 15 years has seen growing awareness about damaging impacts of biological invasions worldwide. A recent estimate calculated the U.S. annual economic impact of biological invasions at more than $130 billion, primarily caused by losses in agricultural lands, forests, rangelands, and fisheries. These invasions and economic costs are expected to increase with growing international trade, the single greatest pathway for harmful introduced species. To combat invasions, a number of local, state, and federal regulations and programs in the U.S. try to restrict harmful invaders and eradicate or manage established ones.

Unfortunately, the present policies, management operations, and research efforts in the U.S. are not working adequately to control invasions because these efforts are fragmented and piecemeal. Several extensive studies have documented specific problems such as insufficient interaction between scientists, policy-makers, and resource and agricultural managers, little framework for rapid responses to new invasions, ineffective use of existing information, too many jurisdictional disputes and turf issues, and few direct means to inform the public about biological invasions. To address these issues, a Presidential Executive Order established the interagency National Invasive Species Council in 1999. This was an important first step and led to the nation's first National Invasive Species Management plan in 2001. However, the Council lacks the infrastructure, support, resources, and mechanisms to implement the plan and to help coordinate the ~650 federal and state programs and non-profit organizations that prevent, manage, and research invasive species nationwide.

A National Center for Biological Invasions, loosely modeled after the U.S. Centers for Disease Control and Prevention (CDC) or the National Interagency Fire Center, is proposed to give the Council the ability to provide national leadership and oversight on invasive species issues and to coordinate and assess federal, state, tribal, and local agency activities. This center would not replace existing legislatively mandated efforts, but rather enhance them.

A new National Center for Biological Invasions could serve several critically needed functions. First, the center could help develop national standards and guidelines pertaining to invasive species prevention and management efforts. Second, the center could coordinate early detection of and rapid response to new invaders between federal, state, tribal, and local agencies and help quick determination of factors that might influence their spread. Third, the center could enhance coordination of existing prevention, control, and research efforts. By functioning as a neutral party, the center could broker cooperative agreements between agencies. Fourth, the center could enhance information exchange among scientists, government agencies, and private landowners through a comprehensive website and merging or coordinating existing databases (over 250 databases currently exist worldwide). Fifth, the center could help track invasive species expenditures for federal, state, and tribal governments; such information would readily be used by policymakers and elected officials. Finally, the center could allow "one stop shopping" for the news media and public education about invasive species in the United States.

Florida's Statewide Strategies for Successful Invasive Aquatic Plant Management

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Florida's aquatic plant management program provides examples of the importance of early detection and rapid response initiatives in eradicating pioneer infestations of invasive plants, as well as environmental and economic benefits of maintaining established invasive plants at the lowest feasible levels. Florida's water hyacinth (*Eichhornia crassipes*) management program also serves as an example of the effectiveness of intergovernmental coordination and cooperation, and public-private partnerships in bringing even seemingly insurmountable invasive species problems under control.

At the national level, the increasing awareness of aquatic invasive species and their harmful impacts accelerated in the late 1990s, fueled largely by problems associated with zebra mussels. In 1999, Executive Order 13112 was signed, calling in part for a national management plan for invasive species management. A draft plan was submitted in January, 2001 outlining nine components for successful invasive species management including: leadership and coordination, prevention, early detection and rapid response, control and management, restoration, international cooperation, research, information management, education and public awareness.

Florida's invasive aquatic plant management program is more than 100 years old incorporating each of the aforementioned elements, some for many decades. However, it was not until the responsibility of coordinating statewide invasive plant management efforts was assigned to one lead agency by the Florida Legislature in 1971 that invasive plants like water hyacinth were brought under control. More than 100 private companies control aquatic plants in Florida and a similar number of local, state, and federal agencies have aquatic plant management responsibilities. The Florida Department of Environmental Protection (DEP) coordinates these multi-jurisdictional efforts through permits, contracts, and interagency agreements to supply financial, technical, and operational resources to control invasive aquatic plants. This cooperative strategy ensures consistent implementation of a statewide management plan while avoiding duplication as well as omitting necessary control. As a result, water hyacinth that once covered more than 50 000 ha of the state's 514 000 ha of public waterways now infests fewer than 800 ha at any given time. Eradicating water hyacinth has proven elusive; however, through frequent inspections and integrating the most appropriate management techniques for the uses and conditions at each site, this once ubiquitous non-native plant has been reduced to a minor component in Florida's multiple use public waterways.

Today, possession of 27 non-native aquatic plant species is prohibited in Florida. Annual surveillance activities document invasive non-native plants in more than 90% of Florida's 450 public lakes and rivers. More than 50 federal, state, and local governments, university and other research institutions, private companies and non-government organizations actively participate in designing, implementing, and monitoring invasive aquatic plant management under the coordination of the DEP. Nearly $30 million are spent annually controlling aquatic plants to preserve attributes such as flood control, navigation, recreation, potable water supply, and fish and wildlife habitat.

Everglades Restoration and the Role of Aquatic Exotics

Bob Johnson
Director, South Florida Natural Resources Centre,
Everglades National Park

This abstract was not available at the time of printing.

A Retrospective Analysis of Response to the Zebra Mussel in North America

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In the mid-to-late 1980s one or more life-stages of the zebra mussel (*Dreissena polymorpha*) were accidentally introduced into Lake St. Clair, MI and/or nearby waters. The mussel proliferated and rapidly spread through the Great Lakes and the inland waterway system, negatively affecting municipal pumping and industrial plants, hydro, fossil and nuclear power generation facilities, locks, dams, vessels and navigation. This was the first freshwater biofouler of any concern to ever reach North America. Facility managers used a variety of strategies to deal with infestations — all with varying degrees of success. Some were highly proactive and purchased equipment and materials immediately; others were reactive and waited for the infestation to occur.

Nearly 20 years after their introduction in North America, we felt that much could be gained with a retrospective analysis of how governmental agencies and mangers of affected infrastructure dealt with zebra mussels, interacted within and among organizations, and what lessons were learned. We identified a set of projects affected by zebra mussels and evaluated each to determine types of and the extent of mussel monitoring prior to infestation, the nature of the strategy (proactive or reactive), and the types of control equipment or materials that were used. The quality and quantity of guidance available to managers to assist them in dealing with the problem is being examined. Finally, facility managers are being asked to supply information on the following: why their approach was successful (or not), what made success possible, what barriers were overcome, and what lessons were learned. Results from this retrospective analysis will enable USACE facility managers to better anticipate personnel and resource needs for dealing with other invasive species should the need arise.

Generation of Life Stage Sensitivity Data to Optimize Chemical Control Strategies

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Chemical control strategies for aquatic invasive species have commonly focused on the control of adult life stages. Adults, however, are often more resistant to chemicals than earlier life stages. A management approach that determines which life stage of an invasive species is most susceptible to different chemical controls, and subsequently targets that stage, would theoretically reduce the necessary treatment application and thus the cost and risk to non-target species, including humans. Many species (e.g., bivalve molluscs) pass through very different developmental life stages (e.g., egg, larvae, adult) that may have significantly different sensitivities to chemicals. This work presents such control-relevant toxicity data derived for several potential chemical controls applied to selected life stages (free gametes, embryos, trochophores, D-stages and adults) of two model invasive bivalves; the freshwater zebra mussel (*Dreissena polymorpha*) and the marine Mediterranean mussel (*Mytilus galloprovincialis*). The data generated include the lethal median concentration inducing (1) 50% mortality (LC_{50}), to compare relative life stage sensitivity, and (2) 99% mortality (LC_{99}), which approximates eradication. Using 24-h laboratory exposures, *D. polymorpha* was subjected to copper ($CuSO_4$ and Cutrine-Ultra®) and *M. galloprovincialis* was subjected to $CuSO_4$, chlorine as NaOCl and the molluscide, Bayluscide®. For *D. polymorpha*, 20 times more chemical was required to achieve 99% mortality in adults (LC_{99}= 1,800 µg Cu/L) than was needed for embryos and larvae (LC_{99} = 14 – 81 µg Cu/L). Similarly, early life stages of *M. galloprovincialis* were much more susceptible to copper, chlorine and Bayluscide; this magnitude was not quantifiable since adults were able to avoid (valve closure) and survive for 96-h in the highest copper (4,484 µg Cu/L) and chlorine (7,500 µg Cl_2/L) treatments. These data also indicated chemical-specific differences in sensitivity between early life stages: for copper, all early *M. galloprovincialis* stages showed similar toxicity (LC_{50} = 8 – 54 µg Cu/L), while for chlorine, gametes (LC_{50}= 36 µg Cl_2/L) were much more sensitive than larvae (LC_{50}= 470 – 717 µg Cl_2/L). In Bayluscide exposures, *M. galloprovincialis* embryos and larvae (12.1 – 31.9 µg /L), which lack shells, were more sensitive than D-stage larvae (LC_{50} = 125 µg /L) that feature newly formed shells, which were more sensitive than three adult size classes (LC_{50} = 226, 424, 500 µg/L). Management plans that focus on early life stages are unlikely to achieve short-term eradication of an ANS population, since by definition; the more resistant adult life stages will survive. Instead, the success criterion must be, in cases where early life stages are more sensitive, to inhibit recruitment. For instance, management may focus on suppressing population growth, and associated damages, by targeting the more susceptible, early life stages of an invasive species. Such management plans require careful consideration of ecotoxicology and population demography, and introduce the potential for coupling life-stage sensitivity data with a matrix population model, to allow probabilistic predictions of invasive species control. While complex, such an approach may offer significant advances in aquatic invasive species control, and can be combined with non-chemical measures (e.g., physical removal of adults) to maximize efficacy.

Microencapsulated BioBullets for the Control of Biofouling Zebra Mussels

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The widespread invasion of freshwaters by the zebra mussel, *Dreissena polymorpha*, during the last two decades has made it one of the world's most economically and ecologically important pests. Since arriving in the North American Great Lakes in the 1980s, zebra mussels have become a major biofouler, blocking the raw (cooling water) systems of power stations and water treatment works and costing US$1-5bn per year. Despite the development of numerous control methods, chlorination remains the only widespread and licensed technique. Zebra mussels are able to sense chlorine and other toxins in their surrounding environment and respond by closing their valves, thus enabling them to avoid toxic effects for up to three weeks. Furthermore, prolonged dosing of chlorine in raw water ecotoxic trihalomethanes (THMs) by reaction with organic material in the water. We have developed a novel, environmentally safe and effective method for controlling the zebra mussel; the BioBullet. Our method uses the encapsulation of an active ingredient (KCl) in microscopic particles of edible material. The mussels' natural filtering ability then removes and concentrates the particles from the water, without stimulating the valve-closing response. By using the mussels' filtering behaviour to concentrate BioBullets the absolute quantity of active ingredient added to the water can be reduced substantially. Our approach allows us to engineer the particles to break-up and dissolve completely within a few hours, thus eliminating the risk of polluting the wider ecosystem. We demonstrate that the effectiveness of a toxin in the control of biofouling filter-feeders can be enhanced greatly by using our technique. This paves the way for a new approach to the control of some of the world's most important economic pests.

New Industrial Uses of Zebra Mussel Filtration Studies: Density Estimation, Particulate Toxin Development and Bio-inspiration of Water Clarification Techniques

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Zebra mussels are prodigious filter feeders and have caused massive reductions in the phytoplankton levels of numerous rivers and lakes around the world. Many authors have investigated zebra mussel filtration to help in the bio-manipulation of eutrophic systems, but this presentation considers a number of new studies of zebra mussel filtration for use in an industrial context.

Firstly, algal removal rates from raw river water are considered as a potential tool in estimating levels of zebra mussel infestation in an industrial pipeline. *Chlorophyll a* levels were monitored in large, flow-through flumes, each containing different densities of zebra mussels. Results show that *chlorophyll a* removal does increase with mussel density, but that at high densities removal becomes limited by particle delivery to the mussels from the water. Dosage of additional algae into the flumes does not improve density resolution, and so these techniques are of limited use in industrial facilities.

Secondly, the high filtration rates of zebra mussels were harnessed in a new method of zebra mussel control, using micro-encapsulated toxins. Commonly-used control toxins were encapsulated in an edible coating that zebra mussels could filter from the water. This allowed zebra mussels to concentrate the toxins within themselves, reducing total toxin requirements. The particles were designed to break down within three hours, eliminating the risk of polluting the wider ecosystem. Field trials revealed substantial enhancements in chemical toxicity to zebra mussels, making encapsulated toxins a highly effective method of zebra mussel control.

Finally. Particle Imaging Velocimetry (PIV) was used to visualise the complex flow dynamics around zebra mussel siphons. Jet-like exhalent flows dominated the vector plots, with surprisingly diffuse inflow patterns. These jets have previously been considered to propel filtered water away from the mussel, but PIV revealed that they may also improve water mixing and delivery of particles to the inhalent siphon. Similar jet-mixing and separation techniques are already used in many Chemical Engineering applications, and may be applied in the development of new industrial water clarification systems.

A Standard for the Control of Zebra Mussels and Quagga Mussels at Ontario Power Generation, Nuclear

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Ontario Power Generation (previously Ontario Hydro) and other Great Lakes water users have been coping with the threat of cooling water supply interruption due to zebra mussel (*Dreissena polymorpha*) and quagga mussel (*Dreissena bugensis*) fouling since these organisms first appeared in the Great Lakes almost 20 years ago. Chlorination has been effective in preventing infestation of service water systems by these mussels.

A Standard has been developed to provide guidance to Ontario Power Generation, Nuclear stations in eliminating recurring challenges from non-native mussels to plant safety and performance. If not controlled, mussel fouling would result in safety concerns, equipment degradation, outages and reductions in station thermal performance. The Standard is intended to ensure that the integrity, availability and performance of critical safety and support systems (cooling and emergency water) are not impaired by mussel fouling. These requirements must be accomplished while meeting regulatory limits related to chlorine discharge and toxicity.

Monitoring is a major component of the Standard. Veligers, pediveligers and juveniles are monitored in station intake water and in bioboxes connected to the station service water system. This monitoring provides information used to determine when to initiate and terminate chlorination each year. Biobox monitoring, in combination with monitoring of total residual chlorine in station service water, is used to determine chlorination effectiveness. Opportunistic inspections of disassembled equipment or components in systems vulnerable to mussel infestation and inspections of submerged water intake structures are also performed.

The ways in which the Standard supports station operation while minimizing the environmental impacts of chlorine will be presented.

Redesign of the Sodium Hypochlorite Treatment Approach for Zebra Mussels at Niagara Plant Group Hydroelectric Generating Stations

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Niagara Plant Group has operated zebra mussel treatment systems using sodium hypochlorite at four of its generating stations since the early 1990s. When these systems were first installed, Ontario Power Generation (OPG) had little or no experience with zebra mussel treatment or the systems and equipment necessary for their control. With this in mind, systems were installed as a temporary measure to respond quickly to the spreading threat of zebra mussels in the Great Lakes with the idea that these systems would eventually be replaced with a better means of treatment. The original treatment approach varied somewhat over time, but typically involved treatment up to 150 days per year either twice per day or continuously in shock mode at concentrations up to 5 ppm. Total annual sodium hypochlorite usage was in the range of 80 to 100 Kl.

After 10 years and a lot of research, it was apparent for the Niagara Plant Group situation that there was no proven treatment alternative for zebra mussel control better than Sodium Hypochlorite. Decisions on had to be made on the replacement of the system as treatment was starting to become ineffective as a result of leaking PVC chlorine piping, fluctuating concentrations, dysfunctional automatic operation and gassing in pumps.

A prototype philosophy was developed using one of the smaller generating stations to re-design the treatment approach from the ground up. The idea was to get it right on the smallest system and then carry on the experience to the other systems. The new approach had to satisfy safety, environmental, operational and cost concerns and needed to be as simplistic as possible. By adopting best practices new types of equipment were utilized that were more durable, and that addressed problems experienced in the original system.

ASI Group Ltd was retained by OPG to provide mussel monitoring services at four Niagara Plant facilities during the 2003, 2004 and 2005 seasons. The scope of the monitoring program was to monitor densities of mussel larvae entering and settling within each facility in order to determine the timing, treatment effectiveness and to help reduce chemical consumption. In order to track the effectiveness of the fixed interval chlorination control programs at each site, bioassays were conducted to determine the effect of the chlorination programs on a daily basis. A successful control was determined when 100% of the adult mussels in the bioassays were killed. By utilizing the integrated approach to controlling mussel infestations by monitoring mussel populations and infestation rates, ASI Group has been able to provide the data necessary for OPG personnel to successfully optimize and refine their control strategy.

The result has been a much more effective treatment system that has reduced operational costs, incorporated measures of effectiveness, and reduced the total amount of sodium hypochlorite released to the environment to the 20 Kl range.

The Use of Potassium Chloride to Control Zebra Mussels in an Open Body of Water

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In August 2002 mussels were observed for the first time in Virginia. Adult mussels were discovered in Millbrook Quarry (Millbrook), a popular recreational diving location, located in Prince William County near Haymarket. Although it is not certain how the mussels were introduced into this isolated water body, it is speculated that human activity was responsible. Regardless of how the mussels were introduced into Millbrook, the Virginia Department of Game and Inland Fisheries (DGIF), in consultation with various federal, state and local agencies determined that the best course of action to deal with the Millbrook mussels is eradication. Although the quarry is ground water fed, and thus is not hydrologically connected to any adjacent waterways or water bodies, its proximity to Broad Run and to two major drinking water reservoirs, Lake Manassas and Occoquan Reservoir, that supply drinking water to over 2 million people and supply raw water to several power supply facilities, indicate that if the infestation were to spread from Millbrook, the impacts would be severe and far reaching.

The DGIF invited multiple firms to submit written proposals for eradication of mussels from Millbrook Quarry located near the Town of Haymarket, County of Prince William and State of Virginia. From information provided in the Request for Proposal (RFP) along with that provided by the DGIF during the pre-proposal meeting and site visit, Aquatic Sciences LP, a subsidiary of ASI Group Ltd. compiled the following summary of requirements, objectives and/or concerns of interested parties and consider them when designing an effective treatment methodology:

- Eradicate (100% mortality) zebra and quagga mussels from Millbrook Quarry
- Residual effect of treatment to control future infestation of mussels in the quarry is desirable
- Sensitivity to surrounding environment (non target aquatic species and organisms toxicity; wildlife and fowl; ground water and surface water quality)
- Long term environmental impacts from treatment
- Sensitivity to the seasonal (April to November) dive operations
- Sensitivity to the property owner and their continued enjoyment of the property
- Site safety and site security
- Post treatment site rehabilitation

Aquatic Sciences proposed that the entire water column of Millbrook Quarry would be infused with potassium by pumping 131,000 kg of muriate of potash (potassium chloride – KCl) solution in to the water body. Evidence suggests that at optimum concentrations potassium kills mussels by interfering with the organisms' ability to transfer oxygen across gill tissue, resulting in asphyxia while not effecting non target organisms. (Aquatic Sciences 1997).

Aquatic Sciences was awarded this project and started the onsite phase on January 17, 2006 with the results pending at the time this abstract was written.

New Technologies for Diverting Introduced and Endemic Fish Species at Industrial Intakes

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Over the past few years behavioral studies on the responses of both selected freshwater and marine species to different deterrents have been conducted in a Great Lakes Lab and at Florida's Institute of Technology's Vero Beach Lab. Much of this work has focused on the USEPA 316(b) rule for power plants that use the once-through-cooling process. The regulation is designed to protect all aquatic life, and reduce impingement mortality by 80-95%, and entrainment by 60-90%. Technologies being developed for diverting non-invasive species at power plants can potentially be used to deter or divert invasive species from sensitive areas (e.g., river systems entering the Great Lakes). Furthermore, many of the species currently being impinged at power plants are exotics.

Different engineering designs will be proposed for potential applications. There are a wide range of potential solutions for preventing fish entry which range from physical screening systems to station modification measures. Three different technologies will be discussed which include a hybrid acoustic-strobe light system, a "reversed" louver system and a pipe based design based on fish space perception tests. Light and sound technologies are examples of a cost-effective hybrid system for diverting fish. Few studies have involved hybrid systems; however, integrated systems are a preferred approach for possibly diverting exotic species. The second technology presented is a unique pipe-based dike. This technology is a modification of a conventional porous dike system. We believe a pipe-based dike technology can be designed such that intake velocities can be minimized below 0.2 ft/s, and therefore can also reduce entrained organisms (eggs, larvae) relative to baseline conditions. The final technology to be discussed is a reversed louver array, where the slats are oriented obliquely to the flow, and tend to divert flow along the louver array. In this technology, slat angles are considered in relation to flow direction (30 to 90 degrees oblique angles), and tend to divert flow towards the louver by-pass channel or along the river. It has the advantage of diverting debris as well as fish.

Results will be presented on a variety of fish species including round goby, gizzard shad, alewife, white sucker, rainbow trout, snook and red drum. Responses varied with species as well as environment (freshwater vs marine). Applications of each technology for preventing fish entry at various locations will be discussed. Further evaluations of these technologies for other species are proposed.

Schools and Science Curricula as Potential Pathways for Aquatic Invasive Species

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Traditionally, schools and classrooms have not been regarded as primary pathways for the introduction of aquatic invasive species (AIS). However, potentially invasive aquatic species organisms such as various species of non-native crayfish and plants (e.g. Brazilian Elodea, *Egeria densa*) are commonly used in classrooms, highlighting a potential AIS problem and providing an opportunity for outreach and education. Live animals and plants used in school curricula can become nuisance species if released outside of the classroom. Educators may not realize that a species can be invasive or that they are using an invasive species in the classroom. Although school districts generally have procedures for the proper disposition of nuisance animals and plants used in the classroom, teachers and students may become attached to the animals and as a result have difficulty euthanizing or disposing of them properly.

Pathways of an AIS Problem

1. Popular science curricula used in classrooms specify the use of organisms in lesson plans that could become aquatic nuisance species if released. (Agencies such as the National Science Foundation often fund the development of science curricula.)
2. Organism suppliers that capture or raise species sale to biological supply houses.
3. Schools order crayfish or other potential AIS from biological supply houses.
4. Schools use crayfish (or other AIS) in science lessons.
5. Once the unit is completed, the class and teacher must decide what to do with the organisms.
6. If no information is provided on the invasive potential of the organisms, the class may decide to release them, resulting in potential ecologic and economic harm.

Prevention Strategies

The aim of our project is threefold:

1. To reduce the potential for schools (through science classroom curricula) to become a pathway for introducing or releasing invasive species.
2. To provide options that blends the concepts and consequences of biological invasions into existing curricula.
3. To create educational opportunities to increase awareness about invasive species among curriculum developers, biological suppliers, teachers, and students.

Prevention Outreach

We are beginning to work with science curriculum developers to develop curricula that include AIS information, options for selecting species, and alternatives to disposal of classroom organisms. The curricula will blend concepts of biological invasions and invasive species prevention into lesson plans. Options will incorporate in-stream learning or preferential use of native organisms. We will provide alternatives to the release of organisms for teachers so they can plan ahead for the disposition of organisms at the end of lesson units. This will help reduce the number of organisms that have to be euthanized.

Work with biological supply houses to ensure they inform schools on the species being shipped and information for properly disposing them. Shifts in demand caused by educating supply houses and curriculum developers encourage organism suppliers to raise less-invasive or regionally appropriate species. Develop AIS literature for biological suppliers to include with the shipments of organisms. Include the aquarium industry as partners.

The success of this project will require multiple partners in a national effort.

Live Food Fish Industry in Canada: Vector and Pathways for Invasive Freshwater Fishes

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The live food fish industry is a major business in North America with a long history of providing consumers with live species for consumption. These markets are generally found in urban areas associated with Asian communities and are growing in number. Canadian data from 2000 to early 2004 indicate that at least 23 types of freshwater fishes were imported for the live food fish markets; nine of which are not native to Canada and two with names not found in the literature. These fishes were imported from the United States, Vietnam and Hong Kong and were farmed or wild-caught. This industry has been a vector for the introduction of invasive species by providing a source of live individuals, which can be released into non-native waters through several pathways. These pathways of introduction can be: accidental release via trucking accidents and deliberate release for religious, ceremonial or ethical reasons. One province has developed legislation concerning the live food fish industry and two more are currently in the process of passing regulations. The federal government has been involved with developing risk assessments for two groups of fishes found in the live food fish industry (Asian carps and snakeheads) and conducting research on the industry and it's pathways of introduction.

Introduction Pathways and Life History Adaptations of Non-native Freshwater Fishes in England

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England has a long history of fish introductions, with the highest number of species introductions taking place during he last 100 years, initiated by the 'acclimitization societies' of the mid-to-late 19th century and intensified during the later half of the 20th century. Initial analysis at the regional level (there are nine recognised regions of England) revealed a relationship between the extent of distribution (no. of regions in which introduced species have been reported) and the number of years since the decade of introduction. Using computer-based import/export and fish movement records, which have become available during the last decade, we examine the pathways of freshwater fish introductions through the analysis of import consignments into England to make an initial assessment of the vulnerability of recipient regions and ecosystems — this analysis reveals three patterns: 1) the number of non-native fish species in regions of England is significantly related to the number of fish imported and the diversity of consignment types (origin of consignment and species imported; 2) the distribution of fish imports has shifted from a concentration in the southwest region of England (89%) to an approximately equal concentration in the SW, the southeast and the northeast regions (about 22-29% each); and 3) the incidence and/or diversity of non-native freshwater fishes (i.e. number of varieties of species) found in the wild has increased dramatically during 1990-2005). We also examine the movements of fish within the country. We also examine the use of biological traits and Categorical & Regression Tree (CART) analysis in predicting invasiveness within a UK context, with some successful invaders, in particular nest-guarding species, (e.g., topmouth gudgeon, *Pseudorasbora parva*) conforming with the CART predictions and others not (e.g., pumpkinseed *Lepomis gibbosus*). The paper concludes with a summary and a few related perspectives are discussed.

Off the Beaten Track: Invasion of "Minimally Exposed" Estuaries in the Pacific Northwest

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The larger estuaries on the Pacific Northwest coast of the United States such as the Columbia River and Coos Bay are heavily invaded, primarily through ballast water discharges, hull fouling, and aquaculture of exotic oysters. Much less is known about the extent of invasion in the smaller estuaries not directly exposed to these vectors. To assess the nature and extent of invasion in this type of estuary, we undertook a study of the soft-bottom communities in "minimally exposed" estuaries in the Columbian Biogeographic Province (Cape Mendocino, CA through the Strait Juan de Fuca, WA). "Minimally exposed" estuaries are defined as those that either have had no or only minor historical exposure to international shipping or to aquaculture of exotic oysters. In comparison, "exposed" estuaries are those that have international shipping ports and/or extensive oyster aquaculture. Data for this comparison were synthesized from the U.S. EPA's Environmental Monitoring and Assessment Program (EMAP) surveys in 1999, 2000, and 2001, from a survey of a suite of minimally exposed estuaries in 2002, and an intensive study of a single minimally exposed estuary (Siletz Estuary, OR) in 2003. In total, nine exposed estuaries and 22 minimally exposed estuaries were sampled.

Preliminary analysis identified at least 17 nonindigenous species in the minimally exposed estuaries. Two of these were freshwater/brackish species (*Corbicula fluminea* and *Potamopyrgus antipodarum*) while the other 15 nonindigenous species were marine/estuarine. Of the marine/estuarine invaders, the amphipod *Grandidierella* japonica and polychaete *Hobsonia florida* were both abundant and wide-spread among estuaries while the polychaete *Pseudopolydora kempi* and bivalve *Mya arenaria* were wide-spread and moderately abundant. All these marine/estuarine invaders were also among the most abundant/frequently occurring invaders in the exposed estuaries. Although approximately twice as many nonindigenous species (32 species) were collected in the exposed estuaries, the nonindigenous species constituted about 20% of the number of native species in both classes of estuaries. However, nonindigenous species were relatively more abundant in the exposed estuaries. Forty-four percent of the stations in the exposed estuaries were classified as moderately to highly invaded compared to only 20% of the stations in the minimally exposed estuaries. This preliminary analysis suggests that exposure to international shipping and/or oyster culture can increase the abundance and diversity of invaders but that at least some of the species introduced into the larger estuaries can disperse widely into other estuaries. As a result of this apparent regional dispersal of invaders from the exposed estuaries, even smaller "pristine" estuaries with no direct exposure to shipping or aquaculture are at substantial risk of invasion.

Potentially Invasive Non-native Aquarium Fish and the San Francisco Bay-Delta Region

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Our study focuses on the rapidly growing aquarium industry that impacts aquatic environments. This industry is little studied but widely recognized to be a significant source of ecologically and economically non-native species. For example, recognized harmful invasive species, such as *Caulerpa taxifolia*, continue to be distributed by the aquarium industry. While much work has examined the effects of accidental, or "hitchhiker" introductions, less attention has been focused on introductions that result from the direct marketing and sale of nonindigenous species. Since little quantitative information is available regarding the risks posed by the non-native species marketed and sold by the aquarium industry, we conducted two separate surveys to:

- Inventory the ornamental fish sold in the San Francisco Bay-Delta region;
- Identify potentially invasive ornamental fish using physiological tolerances and environmental data; and,
- Investigate the level of knowledge about invasive species among store owners/employees

We focused our study on the San Francisco Bay-Delta area, a heavily invaded estuarine system with a wide range of aquatic and terrestrial habitats. The Bay-Delta region is also a major trade hub on the West Coast of North America. For these reasons, it represents fertile territory for the study of industry-mediated species introductions. In the first survey, 54 aquarium store surveys were performed by taking an inventory of every aquarium tank. We identified the type of fish for sale in each tank, along with whether they were freshwater or saltwater species and the tank size (in gallons) in which they were being held. This information was then entered into a database to quantify the diversity of salt and freshwater species sold in the region. Physiological data were obtained from the literature, and basic physiological tolerances such as temperature and salinity ranges were determined for each species for which information was available. Environmental data were identified from U.S. Geological Survey (USGS) surveys and local refugia data. In the second survey, we contacted 30 aquarium stores and asked seventeen questions regarding their general knowledge and opinion on aquarium industry's responsibility for preventing invasions.

- Based on these studies we found that:
- Potentially invasive fish are sold in aquarium stores in the San Francisco Bay-Delta;
- The level of awareness varies among store types; and,
- Opportunities exist for owners/managers to inform customers about invasive species.

This study provides key insights into the magnitude of the invasive species vector represented by the aquarium industry and its potential for facilitating non-native species introductions. By identifying fish types for sale in aquarium stores in the San Francisco Bay-Delta, our aquarium project will help provide the necessary information to better understand the potential risk for introductions through this industry and inform future management, regulatory and policy decisions.

The Scale of Cryptogenesis in the North Atlantic Ocean

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Geographic distributions of shallow water marine and estuarine invertebrate taxa in the North Atlantic Ocean generally fall in one of three categories. An invertebrate species may be: 1) present on either side of the Atlantic; 2) occurring on both sides of the Atlantic, as well as in Arctic or sub-Arctic waters; or 3) present on both sides of the Atlantic, but being absent from the Arctic or sub-Arctic.

Classical biogeographic theory explains these distribution patterns by Pleistocene glaciation, during which northernmost populations were largely or entirely eliminated on either side or both sides of the Atlantic and in the Arctic and sub-Arctic. After the last glacial maximum, these taxa may or may not have subsequently recolonized (from glacial refugia, from southern regions, or from across the ocean) their previous range. Post-glacial colonization via natural dispersal by long-distance transport of larvae and rafting of juveniles or adults on floating substrata are classically seen as the mechanisms for recolonization of distant shores. Historical shipping is generally not regarded of importance in the dispersal and post-glacial biogeographic history of marine and estuarine invertebrates.

Ships with organisms attached to, or burrowed in, their hulls, have moved species around the world for at least 500 years. Ships have moved organisms back-and-forth across the North Atlantic for at least 1000 years. However, only since comprehensive biological surveys began in the mid-1800s have we been able to document the appearance of novel species on either side of the North Atlantic. Consequently, we too often think of biological invasions as beginning in the 19th century, leading to the erroneous assumption that the pre-19th century biota was largely unaltered by the arrival of new taxa as mediated by human dispersal mechanisms.

This assumption has great implications for understanding modern-day distributions of taxa in North Atlantic waters. Key species of coastal communities may have been introduced by ships centuries before the onset of biological surveys, but are viewed falsely as native, whereas they should be considered cryptogenic.

Understanding the importance of cryptogenic species is crucial to understanding biological invasions. A lack of knowledge of cryptogenic species leads to substantial errors in estimating the global numbers, sources, recipients, and impacts of introduced species. This profoundly impacts both our understanding of modern marine community ecology and our basic assumptions about and interpretation of the natural diversity, biogeography and rate of evolution in the seas.

Based on a literature review, and consultation with taxonomic experts, North Atlantic geographic distributions are determined for three taxonomic guilds. Ascidiacea and Hydroida are important members of fouling communities, and are likely to have been transported historically by ships. The distribution patterns of these two groups are compared with the distributions of infaunal bivalves which with few exceptions are not easily transported as hull fouling, and thus serve as a control group.

The relative importance of rafting, pelagic larvae, and of shipping in the dispersal of these taxonomic groups is evaluated, resulting in an estimate of the scale of cryptogenesis in the North Atlantic Ocean.

The Invasive Snail *Bithynia tentaculata* (Gastropoda: Prosobranchia) Carries Deadly Parasites for Water Birds in Wisconsin

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Bithynia tentaculata was introduced into the United States from Europe in the late 1800s via shipping activity. Historically, it has been reported from the Great Lakes Basin and some mid-Atlantic states in the United States. In 1997, *B. tentaculata* was shown to be the intermediate host for an exotic trematode (*Leyogonimus polyoon*) never before reported in the new world. The trematode was responsible for the death of more than 10,000 American coot (*Fulica americana*) at Shawano Lake, Wisconsin, in 1997. Two additional trematodes (*Sphaeridiotrema globulus* and *Cyathocotyle bushiensis*) that use *Bithynia tentaculata* as an intermediate host were found to infect and kill lesser scaup (*Athya affinis*) and American coot during the same mortality event. Surveys conducted in Wisconsin for *Bithynia tentaculata* in 1998 indicated that the snail was in the Wolf River system and east to Lake Michigan. In spring 2002, the death of many lesser scaup and American coot in Lake Onalaska on the Mississippi River was caused by *S. globulus* and *C. bushiensis* indicating that the snail was established in the Upper Mississippi River. Recently, the snail (some infected with *C. bushiensis*) has been found about 70 km south of Lake Onalaska in the Mississippi River. Since 2002, it is estimated that more than 14,000 birds (primarily lesser scaup and American coot) have died on Lake Onalaska from these parasitic infections. Surveys of snails in Lake Onalaska indicate that at many sites *B. tentaculata* are the dominate mollusk species and about 40% are infected with *S. globulus* and/or *C. bushiensis*. Even after snails are dead, viable infective stages of the parasites are found in the apex of the shell, presenting a continued risk of infection to water birds. Under laboratory conditions snails can survive 8 days (probably longer) at 22-23 C suggesting that the snails could easily survive transport without water or moist vegetation.

Secondary Vectors of the Introduced Marine Amphipod *Caprella mutica* on the West Coast of Scotland

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In the last 40 years *Caprella mutica* (Amphipoda), a native species of north-east Asia, has become widely established throughout the Northern Hemisphere and the first sighting from the Southern Hemisphere was recorded in 2004 from South Island, New Zealand. It was first identified on the west coast of Scotland in 2002. Human-aided dispersal is a major contributor to the observed distribution, with shipping (ballast water and hull fouling) and the aquaculture industry highlighted as important global transportation vectors. Secondary vectors of *C. mutica*, once it has established in a new region, are less well understood. At certain times of the year *C. mutica* is found in extremely high abundances (>60,000 individuals m^{-2}) on artificial structures associated with aquaculture activity (e.g. cage netting and mooring lines) and recreational boating (e.g. boat hulls and marina pontoons). This species does not have a pelagic life stage, but is semi-motile and can swim short distances if disturbed. A previous survey of *C. mutica* on the west coast of Scotland has identified several geographically isolated populations associated with finfish farms. The mechanism of introduction to these areas is unknown, although it was hypothesised that inoculation of the sites was through boat movement between farms rather than through natural dispersal mechanisms.

In 2004, the importance of unaided dispersal, recreational boating and drift seaweed as secondary dispersal mechanisms of *C. mutica* were investigated in the Lynne of Lorne, west Scotland. Settlement matrices were deployed around a source population at a finfish farm and at a large marina (in association with current meters) to investigate unaided dispersal and dispersal via artificial vectors (e.g., vessels). A survey of drift seaweed was conducted in the region to determine the role of natural vectors in the dispersal of this species.

The results found that the number of individuals declined significantly with increasing distance from the fish farm (source) population (up to 1km). This suggests that unaided dispersal does not explain the widespread distribution of *C. mutica* on the west coast of Scotland, where the distances between populations can be greater than 50km. In addition, the matrices on the recreational marina were colonised more rapidly and at a greater frequency than those deployed at a distance of 50m, suggesting that boating activity may play an important role as a secondary vector. Individuals of *C. mutica* were also found on drifting algae in the Lynne of Lorne at distances greater than 15 km from the source population.

Unaided dispersal of *C. mutica* can not explain the observed distribution of this species on the west coast of Scotland. The study has highlighted the highly adaptable nature of this non-native species in its ability to utilise both natural and artificial vectors. This feature of the life history may explain the widespread distribution of this non-native species throughout the west coast of Scotland.

Monitoring Nonindigenous Species Across the Mediterranean Sea: The Application of Geographic Information System

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Nonindigenous species (NIS) are continuously reported in the Mediterranean Sea and their spreading across the basin represents a pest for Mediterranean biodiversity with an unpredictable perturbation for local communities and a dynamic no-stop process of colonization. In accord with CBD recommendation, a continuous updating of their distribution is hence necessary in understanding the dynamics invasions and in designing management responses.

In the framework of the Italian project Identification and distribution of non indigenous species in Italian seas, launched by ICRAM (Central Institute of Marine Research) on 2002 and funded by the Italian Ministry of the Environment, ICRAM directed a comprehensive review of the status and distribution of NIS across the Mediterranean Sea. NIS have been grouped into eight broad categories covering all relevant taxa: macrophytes, ascidians, bryozoans, cnidarians, crustaceans, mollusks, polychaetes and fishes. The number of NIS per category and per "Mediterranean geographical sectors" were recorded and discussed according to the following: rate of introduction, vectors of introduction, success of introduced species. The application of Geographic Information System (GIS) allowed to analyze and register large quantities of data and to compare them rapidly and accurately through a spatial and historical perspective. The use of GIS was useful for the comprehension of the invasion dynamics and development furnishing valid inputs for NIS control and managing. The relative importance of the different taxa varied across space and time. Results showed that mollusks were the most important taxon (29%), followed by fishes (22%), macrophytes (16%), crustaceans (12%), polychaetes (11%), cnidarians (5%), bryozoans (3%) and ascidiaceans (2%). The Suez Canal resulted the most important gate to biological invasions across the Mediterranean (49%), followed by maritime transportations (14%), Gibraltar (9%), aquaculture (8%), aquarium introductions (<1%) while many introductions are of unknown origin (20%). The analysis of temporal trend since 1850 showed a gradually increasing NIS income since 1960, concentrated in the Levant Basin; the invasion assumed importance in the central Mediterranean since 1970 and in the western Mediterranean since 1990. The spatial analysis showed a heterogeneous NIS distribution across different geographical sectors of the Mediterranean. Such differences have to be interpreted as the consequences of historical processes and reflect the different oceanographic conditions of these sectors. A few areas, such as the Libyan coasts, appear NIS lacking, probably due to an insufficient system of NIS recording or divulgation. Global change together with sea surface warming occurring in the last two decades in the Mediterranean and the related consequence on the deep current circulation system in the central Mediterranean area seem to play a role in the recent increase of the so called tropicalization phenomenon.

U.S. Coast Guard Aquatic Nuisance Species Program Overview

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Laws passed in the U.S. in the 1990s charge the Coast Guard with addressing a major pathway for the introduction of aquatic nuisance species (ANS) — ballast water from ships. The Coast Guard has been systematically promulgating regulations to reduce the risk of ballast water mediated invasions, with requirements for entry into the Great Lakes and Hudson River in place since 1998 and ballast water management requirements implemented nationally in 2004.

The next regulation to be issued will be a rule defining a ballast water discharge standard that will be used as a performance standard to approve ballast water treatment systems. The need for a discharge standard is underscored by the difficulty in determining the general effectiveness of ballast water exchange as well as the desire to have a means to determine the performance of installed approved equipment. The priority considerations in determining the types of aquatic organisms addressed by a discharge standard is focused on all live forms of all organisms because of the difficulty in predicting which species may become problematic in a particular area. Also critical in the development of the discharge standard is its enforceability as a performance standard for systems installed on ships.

The development of regulations is only the first step in the application of operational requirements to ships for the prevention of ANS introductions. The development of tools and techniques to evaluate compliance and the application of enforcement strategies are essential components to any successful mandatory regime. The compliance and enforcement picture for the current ballast water regulations has shown an excellent trend in increasing awareness and compliance. There are a number of challenges related to verifying compliance with a discharge standard, including determining the appropriate sample acquisition and analysis techniques.

The challenge of determining how to evaluate and approve ballast water treatment equipment has been the focus of several ongoing efforts. The Coast Guard has been working closely with EPA in their Environmental Technology Verification Program (ETV) in the development of protocols for testing the performance of ballast water management systems. The Coast Guard, working in partnership with the Naval Research Laboratory (NRL), has completed a facility for testing ballast water management systems at NRL's laboratory in Key West, FL.

Canada's National Regulatory Approach to Ballast Water Management

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Canada has been active in regulating ballast water discharge from ships for the last 24 years. In 1982, the perceived threat to the aquaculture industry in the Grand Entrée Lagoon of the Isles de la Madeleine from toxic phytoplankton, prompted the Canadian Coast Guard to issue a Notice to Mariners prohibiting ships from discharging their ballast water within ten miles of the islands unless it had been exchanged.

Much has happened on the ballast water and regulatory front in those 24 years. The understanding of the science of invasions, marine engineering and ship operations aspect of ballast water management has been the subject of much research. The invasion of the ruffe and the zebra mussel into the Great Lakes caused Canada to promulgate the Voluntary Guidelines for the Control of Ships' proceeding to the Great Lakes and St. Lawrence River in 1989. In 1998 the Canada Shipping Act was amended to allow a full regulatory regime for ballast water management. By 2000 National Guidelines were in place based on both international guidance provided by the International Maritime Organization (of which organization Canada was an Active participant in the Ballast Water Working groups of the Marine Environmental Protection Committee) and reflecting regional differences for the reality of shipping in different parts of the country.

In June 2005 the Ballast Water Management Regulations were published in the Canada gazette. Incorporating the pertinent regional realities of Canada and many of the provisions of the 'International Convention for the Control and Management of Ships Ballast Water' these regulations will for the basis of Canada's response to the unintended discharge of aquatic invasive species into waters under Canadian jurisdiction.

Compliance and Enforcement with the Coast Guard's Mandatory Ballast Water Management (BWM) Program

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The Coast Guard published two final rules in the summer of 2004 that created a new Mandatory Ballast Water Management (BWM) Program for vessels equipped with ballast water tanks that are bound for all ports or places of the U.S. Together the "Penalties for Non-submission of Ballast Water Reporting Forms" Final Rule published on June 14, 2004, and the "Mandatory Ballast Water Management Program for U.S. Waters" Final Rule, published on July 28 2004, establish mandatory BWM practices and implement penalties for noncompliance with the BWM requirements. In addition, vessels equipped with ballast water tanks must also maintain onboard BWM records, submit BWM Reports to the National Ballast Information Clearinghouse (NBIC), and develop vessel-specific BWM plans. Coast Guard Boarding Officers, Port State Security Officers and Marine Inspectors conduct BWM Examinations in conjunction with regularly scheduled major marine examinations and commercial vessel inspections to verify compliance with the mandatory BWM practices and recordkeeping requirements. To ensure compliance with the reporting requirements, the Coast Guard compares data from BWM Reports submitted and entered in the NBIC database with vessel information records in the Coast Guard's Marine Information for Safety and Law Enforcement (MISLE) Database and Ship Arrival Notification System (SANS). The number of BWM Examinations conducted by the Coast Guard has steadily increased since full implementation of the mandatory program. Within the first year of the program being implemented over 6000 BWM Examinations were conducted by Coast Guard personnel throughout the U.S. and U.S. Territories. The number of BWM Reports received by NBIC has also increased dramatically since January 2004, and the quality of reports submitted continues to improve as electronic reporting becomes more prevalent and additional quality controls are implemented. Coast Guard data reflects a high compliance rate with the mandatory BWM regulations and a growing trend towards even grater compliance.

Canada's Enforcement Regime for new Ballast Water Management Regulations

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Canada has been active in regulating ballast water discharge from ships for the last 24 years. Much of that time the enforcement regime for ships discharging ballast into Canadian waters has been based on voluntary compliance. By working with ship owners, and ships crews, by making industry part of the solution, and working with our trading partners, Canada has achieved an enviable record of voluntary compliance with Ballast Water Management.

With the recent adoption of the International Convention for the Control and Management of Ships' Ballast Water and Sediment, and moves to expand the Ballast Water Management in the United States, Canada has implemented a mandatory regulatory regime. The Ballast Water Management Regulations under the Canada Shipping Act apply in all waters under Canadian jurisdiction. However as Canada is a large country, the realities of geography and the environment are very diverse across the country as is the potential threat of introduction of specific species.

Transport Canada is the lead agency for enforcement under the Canada Shipping Act and is responsible for enforcing a large number of pollution requirements for ships entering Canadian Waters. The intent was to make Ballast Water enforcement no different in context for a Transport Canada Inspector boarding a ship, to other pollution prevention activities.

As such Canada has conceived an enforcement strategy based on the Port State Control regime currently in place for non-domestic ships. As the Secretariat to the Paris (and Tokyo) Memorandum(s) of Understanding on Port State Control, Canada is in a unique position and has been asked to develop Guidelines for Port State Control procedures for the Ballast Water Convention.

Port State Control Inspections for Ballast Water are based on a decision support model that takes into consideration the biogeography of the area where ballast water was taken up and the conditions and vulnerability of the receiving port. Superimposing potentially known species threats into an algorithm based on the international work done by GLOBALLAST, and the Australian DSS system modified for the Canadian experience allow the inspector to understand a real time threat analysis. Mitigation efforts such as treatment or ballast exchange can bring a threat from high to low. Alternative treatments for ballast water such as shipboard or shore side treatment are also incorporated.

The Risk assessment input to the decision support model is region specific so the data incorporated are appropriate and updated.

The presentation will highlight the process, the science and the algorithm and experience to date.

U.S. Coast Guard NOBOB Policy: Best Management Practices for NOBOB Vessels Entering the Great Lakes

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Following the invasion of the Great Lakes by the zebra mussels, Congress enacted the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA), which authorized the Coast Guard to develop regulations for the Great Lakes and Hudson River to prevent the introduction of aquatic nonindigenous species (NIS) into U.S. waters via ballast water discharges from vessels. The Coast Guard promulgated mandatory ballast water management (BWM) regulations in 1993 and 1994, respectively. These regulations require vessels carrying ballast water that enter the Great Lakes after operating outside the U.S. Exclusive Economic Zone (EEZ) to comply with BWM requirements found in 33 CFR Part 151, subpart C.

Vessels declaring No Ballast Onboard (NOBOB) are vessels that have discharged ballast water in order to carry cargo. As a result, they have only un-pumpable residual ballast water and sediment remaining in their tanks that have the potential to carry NIS. A large number of vessels calling on the Great Lakes are NOBOBs and cannot conduct mid-ocean ballast water exchange. As these vessels transit the Great Lakes, they off-load their cargo and take on Great Lakes water as ballast water. Once NOBOB vessels take on new cargo, and discharge the combined (residual and Great Lakes) ballast water, the potential exists for the introduction of NIS into the Great Lakes.

In January 2005, the Coast Guard published a Notice with Request for Comments to solicit public input in the development of effective and practicable management strategies for NOBOBs. In May 2005, we held a public meeting to further engage the public on this issue.

The Coast Guard along with federal, academia and non-governmental organizations, co-funded the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory (NOAA/GLERL) NOBOB Project. According to a NOAA/GLERL Report published in April 2005, the risk of NIS introductions via NOBOBs are associated with fresh and brackish residual waters due to the compatibility of the organisms native to these environments and the Great Lakes. Initial Coast Guard monitoring data suggests that a very low number of tanks from inspected vessels contained fresh or brackish residual water.

After reviewing the results from the NOAA/GLERL NOBOB report, Coast Guard monitoring data, and public comments, the Coast Guard established a policy of best management practices for NOBOB vessels entering the Great Lakes in August 2005. Vessels that enter the Great Lakes with empty ballast tanks that may be filled with ballast water and discharged within the Great Lakes should: conduct mid-ocean ballast water exchange during ballast-laden voyages in an area of 200 nautical miles from any shore and 2000 meters deep whenever possible, prior to entering the U.S. EEZ; or for vessels unable to conduct mid-ocean ballast water exchange, conduct saltwater flushing of their empty ballast water tanks in an area of 200 nautical miles from any shore, whenever possible.

The Coast Guard will monitor the shipping industry's implementation of these practices to assess the level of vessels' implementation of these best management practices.

U.S. Coast Guard Ninth District Program

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The Ninth Coast Guard District oversees the entire Great Lakes region. This region is unique not only because it is the largest above ground fresh water body in the world, but also because it contains an international border. As a closed system, the Great Lakes have faced many challenges over the years and legislation continues to be passed to further protect this international treasure.

The Coast Guard has regulated the ballast water entering the Great Lakes since 1993, providing the most stringent ballast water requirements in the world. In response to recent studies of NOBOB vessels (that is, vessels reporting no ballast on board) and the concerns expressed by different organizations, the Coast Guard published Best Management Practices for these vessels in August of 2005. To verify the effectiveness of this policy, the U.S. Coast Guard and Canada have been jointly taking samples of empty Ballast Water tanks entering the Great Lakes this shipping season. Before 2005 the USCG only sampled vessels with declared ballast water, only 20-30% of all the vessels that enter the Seaway. The program started in 2005 has allowed the USCG and Transport Canada (TC) to better understand the threat of non-ballasted vessels on the Great Lakes.

When a vessel enters the St. Lawrence Seaway it must satisfy three jurisdictional requirements before completing its transit through the locks. The St. Lawrence Seaway Management and Development Corporations have specific requirements of all vessels to ensure safe passage through the locks. Transport Canada enforces Canadian regulations on all vessels that plan to make a Canadian port call. The U.S. Coast Guard likewise conducts port state control and security verifications on all vessels making a U.S. port call. All of these inspections are thoroughly completed but also with an intent of minimizing the delay of the ship.

To address all issues that arise and plan for the future, the Great Lakes Ballast Water Working Group was formed. Members include of the St. Lawrence Seaway Management Corporations, St. Lawrence Seaway Development Corporation, Transport Canada Marine Safety, USCG Headquarters, USCG Ninth District, and the USCG Detachment in Massena, New York. This working group has made great strides towards improving the current system by clarifying required paperwork and procedures, and working towards a single form for use by all agencies' inspectors. Through their efforts and outreach most shipping companies have become proactive in ballast water practices, some requiring more of their vessels than currently required by law.

The partnership involved to solve problems over multiple jurisdictions and with limited resources is historic and will continue to make this delicate habitat an international treasure for centuries to come.

Ballast Water Best Management Practices for Transoceanic Ships: Theory and Practicability

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In recognition that ship-owners and vessel operators must play a major role in minimizing the risk of species introductions via ballast water discharge, a Code of Best Practices for Ballast Water Management ("Code") was proposed by the Shipping Federation of Canada in 2000 specifically for transoceanic ships entering the North American Great Lakes. Since March 2002 the St. Lawrence Development Corporation (SLDC, U.S.) and the St. Lawrence Seaway Management Corporation (SLMC, Canada) have jointly required mandatory compliance with the Code by foreign ships wishing to transit the Seaway. The expectation is that by following these procedures, transoceanic ships can minimize sediment accumulations in ballast tanks and maximize the exposure of freshwater organisms to saltwater, thus reducing the risk of new species introductions. Procedures include, among others, minimizing ballasting operations under the following conditions: in areas identified in connection with toxic algal blooms, outbreaks of known populations of harmful aquatic organisms and pathogens, sewage outfalls and dredging activity; in darkness, when bottom dwelling organisms may rise in the water column; in very shallow water; at locations where a ship's propellers may stir up sediment; in areas with naturally high levels of suspended sediments or in locations that have been affected significantly by soil erosion from inland drainage; and in areas where harmful aquatic organisms or pathogens are known to occur. We discuss the practicability of ships complying with the Code, the effectiveness of and safety considerations relative to ballast tank flushing, which is a potential enhancement to ballast management practices, and the ability to adequately verify and monitor compliance.

The *Mytilus galloprovincialis* Invasion of South Africa – Threats and Opportunities

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Only two marine bivalves have become invasive in South Africa. The Japanese oyster *Crassostrea gigas* recently established significant wild populations in three southern Cape estuaries, where they appear to pose little threat to indigenous species. The Mediterranean mussel *Mytilus galloprovincialis* was accidentally introduced in about 1979 and has since become the dominant rocky intertidal organism along more than 1500 km of coastline, from Namibia to the Eastern Cape. The introduced species is faster growing and more tolerant of aerial exposure than indigenous mussel species. As a result the mussel zone in invaded sites extends further up-shore and displays enormously increased biomass.

M. galloprovincialis has several ecological impacts. It competes with indigenous mussels and limpets for primary rock space. This has greatly reduced the populations of some larger limpet species, although other smaller species thrive by becoming stunted and living on the valves of individual mussels. The dense mussel matrix also provides enhanced habitat for many infaunal species. Because *M. galloprovincialis* occur in such high densities and so high in the intertidal, they have greatly increased the availability of mussels to predators, particularly terrestrial forms, like the threatened African Black Oystercatcher and humans. Although they have radically altered the appearance and community structure of rocky shores in the region, this is not thought to have eliminated any indigenous species.

M. galloprovincialis also forms the basis of a significant local mariculture industry. The potential for small-scale commercial exploitation of wild intertidal stocks by impoverished communities on the West Coast of South Africa was investigated as part of this study. It was concluded that the wild stock could support a maximum sustainable yield of 1560 kg per annum, per 100 m of rocky shore, but that the mussels were only in good condition during relatively short periods of the year. Given this, and the difficulties of transportation to market, it appears unlikely that this enterprise would be profitable.

Perna viridis vs. *Perna perna*: Who Will Win the Invasion Race?

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The bivalve genus *Perna* contains four species namely, the green mussel *Perna viridis* (Linnaeus), the brown mussel *Perna perna* (Linnaeus), the green-lipped mussel *Perna canaliculus* (Gmelin) and the Mediterranean green mussel *Perna picta* (Born). *P. canaliculus* and *P. picta* are geographically restricted to New Zealand and the Mediterranean Sea, respectively. However, the other two species enjoy wide distribution in several parts of the world and often co-exist with each other. Of late, *P. viridis* and *P. perna* have been reported to be vigorously invading new geographical regions. The introduction to new areas has probably been caused by international shipping, either as adults attached to ship hulls or as larvae in ballast water tanks. The mussels have also been introduced to the different parts of the world through aquaculture operations. In regions such as Gulf of Mexico, they have been able to establish themselves into dense populations in spite of the absence of hard substrata. Colonization, especially by *P. viridis* has been quite massive in certain localities (such as Kingston Harbor, Jamaica), often displacing local species. The remarkable success of the two species as an invasive species stems from their long larval duration, fast growth rate, high fecundity, early maturity, high productivity and ability to withstand fluctuating environmental condition.

P. viridis is a mussel commonly observed in intertidal, subtidal and estuarine environments from Indo-Pacific region where surface water temperature generally ranges between 26 and 28°C. *P. perna* is also basically a tropical/sub-tropical mussel. Temperature and salinity are among the most important environmental factors affecting abundance, availability and distribution of marine organisms. The green mussel has wider thermohaline tolerance range than the brown mussel. This may explain why *P. viridis* could displace *P. perna* in some locations. Moreover, collapse of *P. perna* has been reported from certain areas (such as Texas coast of Gulf of Mexico) following warm summers. The observations support the view that relative tolerance to environmental factors such as temperature and salinity may play a great role in the invasive potential of the two *Perna* species and due to its higher tolerance, *P. viridis* may turn out to be a far more successful invader than *P. perna*. The paper presents data on the relative response (lethal and sublethal) of the two bivalve species to environmental stress factors and discusses the data in light of their relative potential to establish in new localities.

The Green Mussel, *Perna viridis*, in the Southeast United States

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Bivalves as biological invaders have received considerable attention, owing to the success of species like the zebra mussel, *Dreissena polymorpha*. A new nonindigenous bivalve, the green mussel *Perna viridis*, was identified in Tampa Bay, Florida, in 1999. The broad objectives of our three-year research program were to monitor and predict the spread of *P. viridis* and to predict major interactions with native species and phytoplankton communities. Our research and results fall into six topics, as follows:

1. Distribution and spread of green mussels. Green mussels invaded Tampa Bay prior to 1999 and spread north and south to the limits of this section of the Intracoastal Waterway. A second invasion was detected in 2002 in northeast Florida, possibly via coastal traffic from Tampa Bay. On the Atlantic seaboard, *P. viridis* has spread from Cape Canaveral north to Georgia, with occasional sightings further north.

2. Potential U.S. range of green mussels. In the laboratory, the 12-day tolerance lower limits of *P. viridis* are 15 ppt salinity and 13°C. *P. viridis* tolerates high salinity in the lab but is uncommon above 28 ppt in the field. Otherwise, field distribution data support lab results. Using water quality data from the National Estuarine Research Reserve System, we predict that *P. viridis* will not survive winters north of South Carolina except in thermal effluents. In Tampa Bay, near-freezing air temperatures killed intertidal *P. viridis*, although subtidal specimens survived.

3. Life cycle of green mussels in Florida. *P. viridis* in Florida has two main spawning peaks: one in early spring and a less-pronounced peak in mid-autumn, based on histological data. This is corroborated by settlement plate data; recruitment begins April-May and ends October-November. Growth is rapid (about 9 mm per month) and some early recruits may reach sexual maturity by autumn. Our growth rate is on the high end of results from Asian studies but other results are consistent with *P. viridis* in its native range.

4. Impacts of green mussels on native communities. In most of its Florida range, *P. viridis* is common but not dominant but, in some areas, it forms dense monocultures that exclude many other species. Artificial structures with good tidal flushing are optimal habitat but adjacent structures with low currents may have no *P. viridis*. Mangroves and seagrass beds are unaffected in most areas but some sites, for undetermined reasons, are heavily impacted. Some oyster reefs are also overgrown by *P. viridis*.

5. Green mussels and phytoplankton: field surveys. Portions of the study areas were affected by episodic blooms of the dinoflagellate *Karenia brevis*. Qualitative data showed that prolonged exposure killed *P. viridis*. Our study also revealed, however, bloom densities of the dinoflagellate *Pyrodinium bahamense*. This species, which produces saxitoxins that can be accumulated by bivalves, had no apparent effect on *P. viridis* survival.

6. Green mussels and phytoplankton: feeding studies. Flow-through feeding measurements using natural seston assemblages revealed that weight-specific clearance rate was positively correlated with chlorophyll flux at flow rates of both 100 and 200 mL min^{-1}. *P. viridis* has the capacity to significantly reduce phytoplankton biomass.

Environmental Changes in the Guaíba Lake, Southern Brazil, After the Settling of *Limnoperna fortunei* (Dunker, 1857)

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An invasive freshwater mytilid native of South East Asia, *Limnoperna fortunei*, is present in South America since 1991, being registered for the first time near Buenos Aires, Argentina. It was probably brought in the ballast water of ships. Since the end of 1998 it was found for the first time in Brazil, at an island situated in front of the harbor of Porto Alegre at the Guaíba Lake, State Rio Grande do Sul. The Lake is a freshwater complex with and extension of 70 km before entering the Patos Lagune. Northward it presents an inner delta formed by four rivers, mainly the Jacuí River, and southward many bays with great extension of rushy areas. The first settling substract of the golden mussel in the Lake was the rhizomes of marginal plants, specially *Scirpus californicus*. In two years the golden mussel population increased on it forming initially flat clusters that growed to large balls reaching densities arround 80,000 to 145,000 ind/m^2. The big clusters formed on the rhizomes induced to the decomposition of the plants by micro organisms. After the decrease in rushy areas, the golden mussels settled on the roots, trunks and submerged branches of small riparian trees, specially the "sarandi", *Cephalantus glabratus*. The weight of the mussel clusters doesn't permit the vertical growing of those plants. Although they became weaker and easily breaking, not more resistant against strong wells, strong flow and the wind. *L. fortunei* also adhered to the shells and soft parts of native bivalves and on the shells and opercula of gastropods, preventing full closure of those mollusks, altering the benthic biodiversity. The rapid change of the marginal landscape and the ecosystem of the Guaíba Lake, observed mainly on the decrease of riparian habitats on the shores, on the diminishing the nestlig and feeding areas for the fishes and other benthic animals; the rapid change of fish feeding behavior, and fishing methods by man are all attributable to the presence of *L. fortunei*. Considering the external shape and behavior, *L. fortunei* is very similar to *Dreissena polymorpha*, the zebra mussel, but it is suggested that the golden mussel should causes more damages to the invaded environment considering that it is bigger in size and reproduces twice a year (Sponsored by FAPEMAT - CNPq – CTHidro).

Invasion Impact Persists After Eradication of *Caulerpa racemosa* Var. *Cylindracea*

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The invasive *Caulerpa racemosa* var. *cylindracea* (Caulerpales, Chlorophyta) native to south-western Australia was observed in the Mediterranean Sea for the first time in Libya in 1991. Within 14 years it spread around almost the entire Mediterranean Sea and even reached the Canary Islands. This is an unprecedented speed of spread for a marine introduced macrophyte. In the present study the recovery of a marine macrophyte assemblage on dead *Posidonia oceanica* beds was studied after manual eradication of *Caulerpa racemosa* var. *cylindracea* over a period of one and a half years ("Eradicated" treatment). Comparisons were made with an uncolonized ("Control") and with a colonized treatment ("Invaded"). Mean percentage cover of *Caulerpa racemosa* var. *cylindracea* was 27.4% (SD 19.9) in the "Invaded", 1.34% (0.7) in the "Eradicated" and 0.9% (0.8) in the "Control" treatment. Mean species richness and macrophyte percentage cover (excluding *Caulerpa racemosa* var. *cylindracea*) were lowest in the "Invaded" treatment (53 species (7), 5.3% (0.9)), intermediate in the "Eradicated" (60 species (5), 8.4% (3.4)) and highest in the "Control" treatment (72 species (5), 13.7% (6.5)). These differences were significant. In a Principal Component Analysis (PCA) the "Control" treatment was clearly separated from the other two treatments. The "Eradicated" treatment had a central position and affinities with the "Invaded" treatment. In conclusion it can be said that the invasion impact clearly persists after eradication of the invasive species in the macrophyte assemblage studied. The assemblage did not return to the original state after one and a half years of eradication of *Caulerpa racemosa* var. *cylindracea*.

Preventing the Establishment of *Caulerpa taxifolia* in the Gulf of Mexico: Detection of *Caulerpa taxifolia* by DNA Analysis

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The Mediterranean clone of the macroalgae *Caulerpa taxifolia* is an invasive species that could potentially be introduced into the Florida marine environment through a public aquarium release. In the Mediterranean Sea, *Caulerpa taxifolia* Med clone (native to the South Pacific) now covers over 13,000 ha of the sea floor, displacing native aquatic plants and altering the marine ecosystem. The *C. taxifolia* Med clone was recently detected in Agua Hedionda Lagoon in California, suggesting that new *C. taxifolia* Med clone introductions could also be anticipated in other coastal areas of North America. We have initiated a survey and monitoring program for *C. taxifolia* Med clone in Florida, making use of PCR assays to distinguish the invasive *C. taxifolia* Med clone from native *Caulerpa* that have a similar appearance. The goal is to identify recent introductions of *C. taxifolia* before they spread beyond the point where eradication is an option.

The PCR assays detect diagnostic features of the *Caulerpa* DNA at two distinct loci; the ribosomal DNA region ITS1 and the chloroplast DNA region *rbcL*. DNA fragments specific to the *C. taxifolia* Med clone are amplified from these regions and distinguished from other species of *Caulerpa* using agarose gel electrophoresis. The PCR assay can be performed in a standard laboratory at relatively low cost. In order to make use of the PCR assays in a detection program, we are conducting surveys in Florida coastal areas deemed to be high risk for an introduction. Because the cost of conducting surveys involving professional divers is prohibitively high, we have devised a website for the purpose of educating the general public about *C. taxifolia* and for engaging volunteers to conduct their own dive surveys. Using the website, volunteers are able to report the coordinates where they have conducted a survey for *C. taxifolia*. Information is also provided to instruct volunteers how to send a suspect *Caulerpa* sample to the Division of Aquaculture for DNA analysis. Results of the DNA analysis are compiled and posted on the website so that users may see the results of their efforts.

To demonstrate the specificity of the PCR assay for the invasive *C. taxifolia* Med clone, we tested various native *Caulerpa* species resembling *C. taxifolia* Med clone from Tampa Bay, the Florida Keys, and the Sebastian Inlet. In all cases, the PCR assays enabled us to differentiate the native species from a *C. taxifolia* Med clone control. The results suggest that DNA analysis will be useful tool for monitoring other Florida and Gulf of Mexico coastal areas that are high-risk for introduction of *C. taxifolia* Med clone.

Management Planning for the Genus *Caulerpa* in Waters of the United States

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Caulerpa is one of the most distinctive algal genera, being identifiable solely on the basis of its growth form and internal morphology. All species and subspecies of *Caulerpa* live in marine environments, but some can thrive in brackish lagoons. Reports on the number of *Caulerpa* species vary from seventy to approximately one hundred most of which inhabit tropical waters.

A variety of surveys have confirmed at least twenty-one species and varieties of *Caulerpa* with populations in different regions of the United States (U.S.). Three species of *Caulerpa* are thought to be a high risk for invasion in U.S. waters due to their historic and ongoing invasions of U.S. and foreign waters; *Caulerpa taxifolia* (Aquarium or Mediterranean strain), *Caulerpa brachypus* and *Caulerpa racemosa*.

In December 1999 the, United States federal, Aquatic Nuisance Species Task Force (ANSTF) established the *Caulerpa taxifolia* (Mediterranean strain) Prevention Committee. The Committee drafted the "Prevention Program for the Mediterranean strain of *Caulerpa taxifolia.*

In June 2000 divers detected *C. taxifolia* (Mediterranean strain) in Agua Hedionda Lagoon located in Carlsbad, California and a second population in Huntington Harbor, California. Divers first discovered non-native *C. brachypus* off the coast of southern Florida in 1999. Concerns have also been raised by scientists about *C. racemosa*, which has spread rapidly in the Mediterranean Sea.

Documented impacts of invasive *Caulerpa* species include competition with marine plants and macroalgae, direct and indirect impacts on marine invertebrates, direct and indirect impacts on marine vertebrates and economic impacts due to control costs and costs associated with ecosystem alteration. To date, eradication efforts for *C. taxifolia* in California have cost over $3.7 million (U.S.) in direct control costs, and over $500,000 (U.S.) have been allocated to study the effects of *C. brachypus* in Florida.

In 2002 the ANSTF recommended that a *Caulerpa* Working Group (CWG) be formed to provide input on the development of a National Management Plan (NMP) that addresses the genus *Caulerpa*. This NMP was developed with the input of the CWG and other *Caulerpa* experts to guide the ANSTF and other interested parties in managing *Caulerpa* species in U.S. waters.

The goals of the United States National Management Plan for the genus *Caulerpa* are:

1. Prevent the introduction and spread of *Caulerpa* species to areas in U.S. waters where they are not native.
2. Early detect, rapidly respond to and monitor *Caulerpa* species in U.S. waters where they are not native.
3. To eradicate *Caulerpa* populations, in waters to which they are not native, where feasible.
4. Provide long-term adaptive management and mitigate impacts of populations of *Caulerpa* species in U.S. waters where they are not native and where eradication is not feasible.
5. Educate and inform the public, agencies and policymakers to advocate for preventing the introduction and spread of *Caulerpa* species.
6. Identify research needs and facilitate research to fill information gaps.
7. Review, assess progress and revise the management plan and continue developing information to meet national management plan goals.

Caulerpa taxifolia: Education and Outreach to the Aquarium Industry, Inspectors, and High School Students

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The ecological and economic impacts of *Caulerpa taxifolia* and *C. racemosa* var. *laetevirins* f. *cylindracea* invasions in the Mediterranean Sea, as well as the costly eradication (US$4.1million July 2000-2002) of *C. taxifolia* in the United States and southeastern Australia, highlight the need for improved education of users and suppliers of *Caulerpa*. Unfortunately, the task of regulating *Caulerpa* is complicated by the high morphological plasticity and large number of species within the genus. Agents who inspect new shipments entering the United States need a way to rapidly identify banned species of *Caulerpa*. We are creating educational materials on *Caulerpa* to distribute to aquarium hobbyists and independent retailers (importers, distributors, and service providers) in California and Florida, two of the most vulnerable areas in the United States for new *Caulerpa* introductions. We also are developing materials that will aid in rapid identification and confirmation of *Caulerpa* species. Training workshops are being held for inspectors to teach them how to identify species of *Caulerpa* and they are given an easy to use dichotomous key that includes pictures and a picture glossary to define the different structures and help them use the key. Evaluation of our outreach strategies will be conducted and results of our successes and lessons learned will be highlighted. In addition, we created curriculum for high school students to help educators and their diverse audiences understand invasive seaweeds, the biology of *Caulerpa taxifolia*, its invasion history, and potential negative impacts of aquarium dumping.

The Federal Aquatic Nuisance Species Task Force: 15 Years of Evolving

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The Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 established a Task Force to coordinate activities between federal agencies, regional, state, tribal, and local organizations involved in carrying out the Act. The United States Congress directed the Aquatic Nuisance Species (ANS) Task Force to develop and implement a program for waters of the United States, to: prevent introduction and dispersal of aquatic nuisance species; monitor, control, and study such species; and educate and inform the general public and program stakeholders about the prevention and control of these species. Since its formation in 1991, the Task Force has worked to meet this broad congressional mandate. Once viewed primarily as a Great Lakes concern and with a focus on the ANS poster child – the zebra mussel – aquatic invasive species is now recognized nationwide as a critical environmental issue. Just as public perception and appreciation of this issue evolved, so has the ANS Task Force. This presentation will look at the development of the Task Force over the past 15 years to its current configuration; some of the lessons learned and organizational adjustments made along the way; and steps it expects to take in remaining a focal point in national efforts to address aquatic invasive issues.

Aquatic Invasive Species and the Review of the Great Lakes Water Quality Agreement: The Opportunities and Challenges that Lay Ahead

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Aquatic invasive species pose one of the greatest threats to the biological integrity and ecological sustainability of the Great Lakes ecosystem. The introduction and spread of invasive species is a complex problem resulting from many possible sources and pathways including: shipping (ballast water discharge, hull fouling, and equipment), canals, live foodfish and aquaria trade, baitfish, and recreational boating. This complex problem is not specifically addressed in the Great Lakes Water Quality Agreement (the Agreement) that commits the governments of Canada and the United States to restoring, protecting, and maintaining the biological, chemical, and physical integrity of waters of the Great Lakes.

The Agreement requires the governments of Canada and the United States to undertake a comprehensive review of the operation and effectiveness of the Agreement every six years. The Agreement is currently up for review. This review process provides an opportunity to ensure that the Agreement continues to be a visionary statement that will guide and foster the two governments' shared commitments to the protection and restoration of the Great Lakes.

To assist them with their review, the two governments requested that the International Joint Commission undertake a study (reference) to solicit public input on all aspects of the review of the Agreement. This paper summarizes the public input on the opportunities and challenges that lay ahead to address the impact of invasive species to the Great Lakes. This information was received through public consultations carried out by the Commission under the study from September 2005 to January 2006. Additionally, the paper provides the Commission's recommendations to strengthen the Agreement with respect to addressing the threat of aquatic invasive species to the Great Lakes basin ecosystem.

The Aquatic Invasive Species Action Plan for the Great Lakes: The Results of Regional Collaboration Under President Bush's Executive Order of May, 2004

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In May 2004, President Bush signed an executive order that set into motion a large-scale planning process for Great Lakes restoration. Under the executive order, eight "strategy teams" were formed to develop action plans for issue areas. One strategy team was tasked with developing an Aquatic Invasive Species (AIS) Action Plan. More than 200 individuals representing all levels of government, NGOs, and industry participated in the development of the AIS Action Plan. This plan was developed through a consensus-based process using five drafting teams to focus on AIS pathways. Through a series of meetings and conference calls, the teams refined the conclusions of the drafting teams to develop a comprehensive list of recommendations, a list of near-term priorities, and estimate implementation costs. Recommendations included actions to address the introduction of species through aquaculture, ballast water discharge, canals and waterways, the trade of live organisms, and recreational activities. The expectation is that this action plan will serve as a guide to decision-makers as they implement effective AIS policy. This process serves as a model for development of prevention and control approaches for other large ecosystems.

Establishment and Operation of a National Center for Biological Invasions in the United States

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Federal agencies spend about $1.2 billion annually on preventing and managing invasive species in the United States. The results have been mixed. While progress has been made on specific projects, usually focusing on specific species or regions, consistent national leadership under one umbrella does not exist.

A National Center for Biological Invasions has been proposed. If many of the groups currently working on invasive species management, research, and outreach were coordinated on all levels – local, state, regional, and federal – in a manner that filled a needed niche and supporting existing efforts, the challenge of prevention and control would likely be more successful. Those already involved could work together, rather than separately or in competition.

Such a center requires thinking outside of the box about leadership, public support and funding. It could evolve from one coordinated effort, similar to the evolution of the U.S. Centers for Disease Control and/or the National Interagency Fire Center. The key is meeting needs of and involving state ANS managers and goals.

This presentation, complementing "Why We Need a National Center for Biological Invasions in the United States," by Don Schmitz of the Florida Department of Environmental Protection, will describe possible resources that already exist to operate such a center and suggest an evolutionary strategy for developing such a center through grassroots support.

Facilitating the Development of an Invasive Species Management Plan for the Commonwealth of Pennsylvania

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Invasive species pose a significant threat to the economy and ecology of Pennsylvania. Zebra mussels (*Dreissena polymorpha*), purple loosestrife (*Lythrum salicaria*), Asian stiltgrass (*Microstegium vimineum*), giant hogweed (*Heracleum mantegazzianum*), and northern snakeheads (*Channa argus*) are just a few of the invasive species that are changing the ecosystems of the Commonwealth.

In January 2004 Governor Ed Rendell recognized the need for increased coordination and communication on invasive species prevention and control and issued an executive order to form the Governor's Invasive Species Council. The Council is charged with 1) advising the Governor on and directing the development and implementation of a state invasive species management plan; 2) providing guidance on prevention, control, and rapid response initiatives; and 3) facilitating coordination among federal, regional, state, and local efforts. The Council had its first official meeting in October 2005.

Development of the Pennsylvania Invasive Species Management Plan began with a workshop in October 2005. Because the Invasive Species Council deals with both aquatic and terrestrial invasive species, the management plan also focuses on both aquatic and terrestrial issues. This raises additional challenges but also provides unique opportunities for cooperation and collaboration. The workshop brought together on-the-ground managers, state policy makers, commercial stakeholders and NGO representatives to develop goals and objectives for where Pennsylvania invasive species management should be regarding prevention, early detection, rapid response, control, education, and policy/coordination. The workshop highlighted current issues and impacts of invasive species within the Commonwealth, as well as lessons learned from other states. An associated implementation plan is now being developed to identify the necessary steps to reach those goals. This talk will highlight both the successful aspects of facilitating the development of an invasive species management plan for Pennsylvania, and the challenges that have arisen with the approaches used.

Invasive Species Policy: A Need for Action

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Presidential Order 13112 issued on February 3, 1999 by President Clinton created a National Invasive Species Council. Invasive species as defined in that order means "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health". Invasive species are a serious problem that government at every level and branch has to face. Invasive species do not respect political boundaries or ecosystem types. No pathway appears immune from use as a potential means to introduce invasive species. Passengers, cargo, freight, luggage, or mail by air, sea, car, truck or rail, does not seem to matter. Governments spend millions of dollars annually trying to combat these invaders. To date, success has been limited to individual focused efforts on particular species. Traditionally, most efforts have been on readily observable harm, such as, but limited to Dutch elm disease, gypsy moth, citrus canker, BSE, exotic Newcastle, West Nile, and AIDS. However, despite the amount of money spent on surveying, control and eradication methods, invasive species keep coming. Citizens look to their government for answers or at least, direction. From the government perspective, the problem has been that science has never been able to offer a single or simple answer to the invasive species problem that fulfills the requirements of a democratic government. General conclusions or guidance decisions hold no water in today's litigious society. Consequently, improper or no planning, indecision or poor decisions all delay actions that increase the cost of eradication or control of invasive species. Government employees from the front line biologists to the last line, policy makers, must make decisions based on information and facts that can withstand public scrutiny. Government, regardless of whether it is the executive or the legislative branch, needs reasonable and defendable information that can be used to establish policy that will work. Public support, either general or focused must be present for resources to be allocated. In the last 10 years in Florida, the public has demanded less government not more. General government operations must use fewer resources, while education, public safety, corrections, and health providers must have more resources. Demographics point to an aging society that focuses on health care and entertainment activities. No one has made the case in the public's eye that invasive species, as a category, must be addressed at any cost. The voting public does not even think these organisms as a whole are a problem. To that point, even Congress has failed to reauthorize the National Invasive Species Act for the last three years. Invasive species are a serious problem that can fundamentally undermine the very economic base that governments depend on for operations. Researchers and decision makers alike need to cooperate and coordinate in a concerted effort to generate the information necessary to demonstrate the need for resources to be allocated to protect our selves and our economy.

National Aquatic Species Risk Analysis: A Call for Improved Implementation

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There has been recent criticism of the risk analysis process, the Generic Nonindigenous Aquatic Organisms Risk Analysis Review Process (Generic Analysis) developed in 1996 by the Aquatic Nuisance Species Task Force (ANSTF), used by federal agencies in the United States. Although some criticism is justified, we argue that critics as well as federal agencies implementing the process have focused on the risk assessment and have ignored the other vital facet of risk analysis, namely risk management. The first step in the Generic Analysis is to complete a risk assessment that consists of 1) identification and input of interested parties; 2) information collection on the pathway or organism and associated organisms (literature and investigation); 3) qualitative or quantitative risk assessment to judge the probability and consequences of establishment along with the assignment of uncertainty ratings; and 4) recommendations. The second step is risk management to determine appropriate policies, operational measures, and adaptive management components built upon the foundation of published information, expert and stakeholder input, and risk prioritization created by the risk assessment. Effectively, risk assessment organizes the information on a nonindigenous species or introduction pathway and categorizes and prioritizes risks whereas risk management defines the steps to be taken to mitigate risk. Although the process envisioned by the ANSTF included both components, there has been only a single integrated effort at combining risk assessment and risk management (i.e., a sturgeon culture risk analysis conducted by a state agency). Unfortunately, five efforts in the United States and one in Canada have used only the risk assessment portion of the ANSTF Generic Analysis. In addition, there are two cases of the use of risk management without a previous risk assessment. Although risk assessment and risk management are distinct, they should not be conducted in isolation. Risk management is particularly important in cases where a risk assessment predicts high risk. If risk assessment and risk management are effectively coupled as the authors intended, the results will yield effective, practical and timely prevention, control, and management programs that integrate federal, state and NGO efforts to reduce the fragmentation of federal and state efforts that is a frequent and valid criticism of federal efforts. The stakeholder synergy created by combining risk assessment and management yields results far greater than assessment or management planning completed in isolation.

The Legal Implications of Mandatory Identification Systems for Aquaculture Operations

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In June 2003, the Maine Department of Environmental Protection issued an amended General Permit for Atlantic Salmon Aquaculture pursuant to the state water quality laws. The General Permit contains a controversial provision. "By July 31, 2007, all fish placed in net pens must be identifiable through external means as commercially reared and identifiable as to the individual facility into which they were placed." The U.S. Army Corps of Engineers is developing a similar marking requirement for its aquaculture permitting program.

These marking programs are good news for invasive species management. Escaped fish have the potential to out-compete native fish, introduce diseases into wild populations, and affect genetic diversity through interbreeding. The introduction of non-native and/or invasive species is prohibited in almost every state. With the vast majority of introductions, however, it is impossible for managers to identify the culprit. The marking requirements in Maine and under consideration in other states will change that, at least with respect to the aquaculture industry. Finally, managers will know who is responsible. And now that escapees can be traced back to a particular facility, enforcement actions can be taken if necessary.

Although marking programs are not being developed to aid enforcement of environmental laws, the tool will not be ignored by the law enforcement community for long. The litigious nature of the U.S. almost guarantees that lawsuits will quickly follow a large escape event. A number of legal issues need to be addressed as these marking programs are implemented. First, facility operators need to know whether they can be held legally responsible by either the government or a private individual if their product escapes. For instance, in Maine "when an animal damages a person or that person's property due to negligence of the animal's owner or keeper, the owner or keeper of that animal is liable in a civil action to the person injured for the amount of damage done if the damage was not occasioned through the fault of the person injured." (7 Maine Rev. Stat. § 3961). If a fish from Farm A escapes and transmits a disease to Farm B, Farm B's operators might have a cause of action against Farm A's operators under § 3961.

Facility operators might also be found liable for damages caused by escapees under tort law. A finding of civil liability will turn on whether an operator was negligent. Is the mere existence of an escapee in the wild enough to prove the operator was negligent? Escapes can happen for a number of reasons some of which, like storms, are out of an operator's control. What duty of care, if any, does a facility operator owe to other facility operators and the general public? The legal consequences of these marking programs must be examined and addressed by policy-makers before implementation to ensure that facility operators are not exposed to unintended liability risks. This presentation will examine a number of the legal issues associated with mandatory marking programs and identify areas of concern for policy-makers.

Successful Eradication of *Caulerpa taxifolia* in California Through Rapid Response and Team Approach

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Two populations of the marine invasive green alga *Caulerpa taxifolia* were discovered in southern California in 2000, both of which were in protected embayments with direct connections to the Pacific Ocean. The Agua Hedionda site, located in Carlsbad, CA (48km north of San Diego) is comprised of three interconnected basins (ca. 140 ha total), the innermost of which contained one large and several smaller colonies of *C. taxifolia* totaling approximately 12,000 m^2 . Huntington Harbour, located near Long Beach, CA had scattered colonies in two small (ca. 2ha each) basins and a few small colonies in the adjacent main harbor. Following the confirmation of species identification, a rapid assessment and review of response options was completed within three weeks of the discovery, and the first containment/eradication treatments were made less than 30 days after the discovery. After scuba divers contained colonies of *C. taxifoila* beneath PVC tarps and treated colonies with liquid sodium hypochlorite or solid pellets (trichloro-S-triazinetrione), extensive follow up monitoring (two to three per year) and re-evaluations were continued through 2005. The crucial, first steps were taken by representatives of several federal, state, local, private and non-governmental groups that later comprised the Southern California Caulerpa Action Team, "SCCAT". (Co-authors on SCCAT Steering Committee: L.Anderson, B. Hoffman, W-MSmith, B. Paznokas, B. Posthumus). Throughout the past five years, SCCAT has had to resolve a plethora of issues ranging from appropriate eradication methods, regulatory requirements, sources of funds, implementation of treatments, assessment of treatment efficacy, quality assurance of surveillance methods, public outreach, and development of eradication criteria. In addition to bi-monthly meetings of SCCAT, several meetings of the SCCAT Technical Advisory committee provided on-going scientific input. An Outreach Committee provided extensive public educational materials, briefings and provided updates on progress. The fall/winter surveys of both sites, completed in December 2005 showed no *C. taxifolia*. Based on divers' demonstrated ability to detect colonies of different sizes, coupled with estimates of potential growth (colony expansion), the negative 2005 surveys provided sufficient evidence that all colonies had been destroyed. The last live *C. taxifolia* was found in Agua Hedionda in September 2002 and in Huntington Harbour in November 2002. The success of this

project hinged upon cooperative discussions and timely actions of SCCAT members, and having resources (funds and an implementation team) available within a few weeks of the discovery of *C. taxifolia*. The ability to sustain resources for the required five-year project necessitated continued applications for funding from various state and federal funding sources (e.g. environmental grants), and continued commitments of in-kind resources from SCCAT members. Combined costs for containment, eradication and related outreach/public education will approach US$ 5.5 million, not including significant in-kind resources provided by members of SCCAT. We believe that the effective components of this project, facilitated by the style and culture of science-based, open adaptive management can serve as a model for successful rapid response to new incursions by other invasive species.

A Molecular Diagnostic Approach to the Detection and Management of Marine Invasive Species from Ballast Water

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Ballast water employed in industrial shipping enterprises has been identified as one of the key vectors for the introduction of non-native marine species to ports throughout the world including those in Puget Sound. Therefore, the regulation of non-local ballast water influx to local harbors is recognized as essential for maintaining local ecosystem health and the continued success of native species. Currently, no predictive criteria exist for determining which non-native species will become invasive when introduced into a given environment. This observation suggests that the most successful methods for screening ballast water should detect the presence of as many different species as possible and be highly iterative in order to deal with the large volumes of ballast water involved. To these ends, we have been developing nucleic acid based molecular diagnostic tools to detect the presence or absence in industrial ballast water of various marine species known to have planktonic life history stages. The latter consist primarily of bivalves and crustaceans but also include marine macroalgae, copepods, cumaceans, tunicates, echinoderms, microorganisms and other groups known to contain species that have proven invasive in non-native marine environments. Our molecular approach involves the development of species or genus specific molecular markers in conjunction with microarray technology resulting in a system capable of quickly screening a given sample for thousands of species simultaneously. Subjects to be included in the microarray are first collected as adults and identified to species before sequencing of the intergenic ribosomal DNA spacer regions (ITS1, ITS2, 5.8S). Species or genus specific markers developed from these data can then be used to create molecular beacons in the form of peptide nucleic acids (PNAs) which are subsequently added to the microarray. In this way, a single iteration using the resulting microarray, simultaneously tests for the presence or absence of all species included on that array. Equally important, treatments of ballast water to render reproductively-capable potential invaders non-viable should be followed by additional screening processes that yield information regarding whether or not any viable individuals remain. Various approaches to culturing, whole-cell staining and flow cytometry are currently being employed in our laboratory to assess organismal viability.

The Transfer of Plankton Species in Coastal Ballast Water

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Ballast water is an important vector for introduction of nonnative species to the Columbia River. Some of these introduced species, such as the Siberian prawn (*Exopalaemon modestus*) and the Asian copepod (*Pseudodiaptomus forbesi*), are now dominant members of the Columbia River zooplankton community. Transport of ballast water from the ports of Stockton and Sacramento pose a high risk to the Columbia River because the environmental conditions at these ports are similar to the Columbia River, the voyage duration is short, and the Bay/Delta region in California has many species that are not native to the Columbia River. We characterized the risk of ballast water-mediated introduction by determining the species transported in freshwater ballast and estimated their survival following ballast water exchange. We sampled plankton in ballast water on a ship before and after ballast water exchange during three voyages from the Port of Sacramento, CA, to the Port of Vancouver, WA. Thirty-six species of plankton were found in ballast water tanks; 20% have not been found in the Columbia River. *P. forbesi* was found at densities as high as 14,700 per cubic meter. 42% of the species in ballast water from Sacramento were either confirmed introductions or cryptogenic species in the Columbia River. The abundance of freshwater and estuarine species transported with ballast water from Sacramento was reduced by 95% or more when the ship arrived at Vancouver, due to natural tank mortality and ballast water exchange.

Potential for Introduction of Non-native Marine Species in Select Caribbean Ports Receiving Cruise Ship Traffic and Possible Mitigation with Ballast Exchange

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One of the most critical factors in successful translocation of non-native marine species is the frequency of introduction. Cases of introduction in ports receiving bulk cargo and with large in-ballast volume are well documented. Less well studied are those ports with a very high volume of repeated traffic but lower ballast volume discharge. The potential for introduction of exotic species from the Caribbean by ships making repeated transits along fixed cruise tracks was examined using a unique cruise ship laboratory platform for data collection. The Explorer of the Seas, a collaborative venture between the University of Miami and Royal Caribbean International, has on board, instrumentation which continuously record data along the cruise track. Mounted on the ship are two Acoustic Doppler Current Profilers (ADCP) which record surface water movement, and various sensors for salinity, CDOM, chlorophyll and particle distribution. MODIS satellite images of the area supplement this information. The cruise track starts in Miami, FL, with stops in several Caribbean ports (San Juan, Puerto Rico; Charlotte Amalie, St. Thomas, USVI; Philipsburg, St. Maarten; Nassau, Bahamas) before returning to Miami.

While the overall range in values for salinity, chlorophyll and CDOM is small, these data were nevertheless important in determining the four distinct water masses that the ship encounters along its route: the Florida Current, the Bahamas Bank, the Western Atlantic, and the Inter-Island passages between San Juan and St. Maarten. Biological productivity along the cruise track varies from the low productivity oligotrophic waters of the western Atlantic to the nearly eutrophic conditions of large island harbors as in San Juan. Blooms vary with season and storm fronts. Mesoscale eddys, large whirlpools of circulation from kilometers to hundreds of kilometers across move through the Caribbean basin and along the eastern edge of the Bahamas. In general, it appeared that CDOM and particle counts tracked each other, while salinity showed an inverse relationship to the two measurements.

On board, the efficacy of ballast tank flush and fill was monitored with rhodamine dye and ATP analysis. The results showed rhodamine fluorescence to decrease by a factor of 10 with each flush and fill event, as expected theoretically; after the third flush and fill event, the fluorescence was 0.1% of the original amount. As an index of the viability of planktonic species, ATP assays performed on both external water and ballast tank water showed the presence of viable organisms. Regardless of the flush and fill event, ATP was always present water samples taken from the ballast tank.

Results indicate that a laboratory equipped ship repeatedly traversing a region offers the ability to collect reliable data, relevant to questions of potential invasion threats, and mitigation processes. Our data clearly described and located the different water masses through which the ship traveled, and therefore the associated risks of contact with potential aquatic invaders. Ballast exchange experiments were timed to coincide with select external water qualities, and exchange efficiency was determined under various but defined conditions.

Decision Support to Reduce the Risk of Introduction of Aquatic Organisms by Maritime Commerce into Delaware Bay and Other Port Ecosystems

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Although impacts of species introduction are clearly ecological, those ecological impacts produce socio-economic consequences. Because ballast water can be a vector for transfer of human pathogens, its discharge may have human health consequences as well. In response, this past February, the IMO adopted the Ballast Water Convention and called for the use of "suitable decision-making tools" to analyze ballast water management protocols.

IMO Ballast Water Convention will require the attainment of ballast water concentration-based discharge performance standards between 2009 and 2016, depending on vessel class, size, and construction date. Individual States can set more stringent performance standards, and, based on IMO risk assessment guidelines, may exempt a ship taking a voyage between specified locations. Significant attention thus will be directed toward examining which trade routes and vessel types present the greatest risk of species introduction; which suite of technologies will need to be employed on a vessel of a particular class that follows a specific route to achieve the specified discharge standard; the least cost solution for that vessel; and cost-effectiveness of the present standard and/or alternative standard(s).

The use of linear (and nonlinear) programming to explore tradeoffs between cost and benefits of new technology and to derive optima has a long history of use in energy-related sectors. More recently, Corbett and Winebrake have used it to derive optimal air pollution reductions from passenger ferries. Previously, we developed a ballast water discharge compliance and policy support optimization model. Here, we employ General Algebraic Modeling System (GAMS) linear programming software to operationalize the model and evaluate the potential for technology-policy alternatives to mitigate introductions of aquatic organisms from ballast water. Our analysis is motivated by five objectives: minimizing the number of viable organisms discharged (or, alternatively achieving a specified standard); reducing the time needed to achieve reductions; minimizing total cost (public and private); protecting particularly sensitive ecosystems; and maximizing technology adoption by vessels according to their relative risk of introducing organisms. The model constraints and objectives can be set to directly evaluate some of these objectives in an optimization context; other objectives and overall decision support insights are provided by our related analysis. The presentation will include an overview of the model followed by its application to a specific port ecosystem, Delaware Bay. Yet, as we will demonstrate, the model is flexible enough to consider any port ecosystem in the world, and importantly, can be modified and enhanced as new information becomes available.

More specifically, we analyze potential reductions in organism discharge concentration and quantity, costs, and cost-effectiveness of different combinations of technologies and policy approaches to identify a set of candidate technology policies that may achieve environmental policy goals for Delaware Bay at least cost. We evaluate the risk of introduction based on several factors, including commercial vessel type entering/clearing Delaware Bay ports, ecosystem characteristics, treatment-method effectiveness, and voyage duration. Policies modeled include the status quo (ballast water exchange), IMO convention concentration limits, limits on the total number of viable organisms that may be discharged, and market-based mechanisms.

Ballast Water Sampling and Options for Rapid Sample Analysis

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One of the key issues in "invasion biology" today is representative sampling of ships ballast water. Although there were repeated ballast water sampling programs, no standardized sampling method was agreed upon. A few programs have been carried out to check for the efficacy of certain sampling methods.

However, even the best methods were not considered sufficiently advanced to enable rapid sampling onboard ships and to provide representative results of the species community inside ballast tanks. Sampling ballast water is of particular interest to verify compliance with (a) national requirements, (b) the ballast water discharge standard as set forth in the new International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (IMO Convention), and also (c) to proof efficacy of ballast water treatment systems. This contribution will highlight sampling relevant issues of the IMO Convention and related guidelines and will also introduce a new sampling device for timely and accurate sampling of zooplankton. In addition, we introduce tools for rapid sample analysis onboard ships and in land-based testing facilities.

In-line Pipe Sampling Methods for Continuous Sampling of Ballast Piping Systems

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For multiple environmental and economic reasons, there is a global, political and scientific momentum to diminish the translocation of invasive and nonindigenous organisms through ship's ballast water. Since 2001, the Naval Research Laboratory in Key West, Florida has been addressing this need through the construction of a full scale testing facility to evaluate candidate ballast water treatment technologies. One test facility objective is to provide standardized challenge water at shipboard flow rates across all applicable testing conditions. Challenge water is created through the controlled introduction of surrogate organisms and organic and inorganic particulates, to ambient feed-water at specified concentrations. These biological and chemical parameters will be sampled at pre- and post-treatment sites during testing and discharge. Currently, the pilot facility is performing pretreatment runs for physical and biological calibration purposes. The effects of the system's sampling configurations on marine surrogates are being assessed. The goal is to maximize the volume sampled while minimizing surrogate loss through mortality or removal. An initial evaluation on the system's in-line and in-tank sampling design has been conducted in which a zooplankton surrogate, *Artemia franciscana* was injected and sampled. Discussion of the full scale injection and sampling of this surrogate is reported.

Biological In-tank Sampling and Sample Degradation for Standardized Ballast Water Treatment Technology Sampling

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Verification testing of treated ballast water requires counting of very low concentrations of organisms in very large volumes of water. Regulation D-2 of the "International Convention for the Control and Management of Ships' Ballast Water and Sediments" calls for less than 10 viable organisms per cubic meter greater than or equal to 50 micrometers in minimum dimension. Organisms in this size class in a ballast tank require some method of concentration such as collection with plankton nets. Statistically rigorous counting of viable organisms within a ballast tank requires robust, well designed sampling procedures and apparatus that maximize the sampled volume and maintain viability of the sampled organisms over the sequence of ballasting, sample collection, deballasting and sample analysis. Constraints of the mechanical sampling system include ballast tank geometry, plankton net geometry and materials, initial and final net positioning, net mesh size and net velocity within the sample volume, and sample wash down and collection procedures. A winch driven ballast tank sampling system is described which utilizes custom plankton nets and a mechanical guidance system with a seawater washdown. The purpose of these is to concentrate and maintain viability of organisms within the test and control ballast tanks at the Ballast Water Treatment Test Facility at the Naval Research Laboratory in Key West, Florida.

Does Open-ocean Ballast Exchange Prevent Transfer of Invertebrates Between Freshwater Ports?

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To prevent the introduction of nonindigenous species to the Great Lakes, ballasted vessels are required to exchange fresh or brackish ballast for open-ocean water if they intend to discharge it within the system. Similar guidelines for non-ballasted vessels have recently been developed, encouraging them to expose residual ballast water and sediment to open-ocean water. The goal of open-ocean ballast water exchange (BWE) is to flush freshwater organisms out of ballast tanks, with an additional benefit of killing those that remain with high salinity water. Although BWE is currently the accepted measure to prevent invasions, empirical data on the effectiveness of this treatment is unavailable. To test BWE efficacy, we ran controlled experiments in paired ballast tanks of four transoceanic vessels transiting from the Great Lakes to Europe. Experiments assessed the impact of BWE on live planktonic invertebrates, recruitment from diapausing eggs, and on subsequent egg viability. BWE was >99% effective for removing freshwater planktonic invertebrates. BWE eliminated recruitment from diapausing eggs, but did not affect their viability when the eggs were returned to freshwater. Although BWE appears highly effective for live animals, other treatment options will be required to eliminate risk of invasion via diapausing eggs.

Individual and Combined Effects of Sonication and Advanced Chemical Oxidants as Mechanisms to Eradicate Various Life-History Stages of a Model Aquatic Macroinvertebrate Under Static and Continuous Flow Regimes

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Ballast water is one of the primary conduits for the transport and discharge of non-indigenous species into aquatic and marine ecosystems. Planktonic organisms and their early life-history stages (cysts and larvae) of various species form the bulk of the organisms being transported via ballast water. The highly robust Brine Shrimp, *Artemia salina*, with its three distinct life-history stages (cyst, naupliar larva and adult) was selected as a model organism to investigate the effects of individual and combined treatments of sonication, hydrogen peroxide and ozone on mortality. The effects of these treatments were analyzed using different time periods of exposure ranging from 1 to 20 min under both static and continuous flow regimes. Combined treatments of sonincation, hydrogen peroxide and ozone yielded the highest mortality rates. 100% mortality was obtained for larvae and adults under both static and continuous flow regimes, while mortality levels of 93 and 91% were obtained for cysts under static and continuous flow systems, respectively. Combined treatments also required significantly less exposure time to inactivate cysts, larvae and adults. The results of the study indicate that sonication combined with advanced oxidants such as hydrogen peroxide and ozone may be effective in the eradication of various life-history stages of aquatic and marine macroinvertebrates in ballast waters.

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Some Biological Consequences of a Nonindigenous Forage Fish on Lake Trout and Other Salmonids Populations in the Great Lakes Basin

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Alewife (*Alsoa pseudoharengus*) entered the Great Lakes with the opening of the Erie Canal in 1825 and the St. Lawrence Seaway in 1959. In the mid 1900s alewife became the predominant fish species when the predators were extirpated and native forage species declined. When predatory species (salmonines) were reintroduced, alewife was the main forage consumed. Over the past 10 years our research on early mortality syndrome (EMS) has shown that thiamine deficiency may be linked to a reproductive bottleneck observed in lake trout and salmon feeding on alewife in the Great Lakes. Alewife contains an enzyme, thiaminase, which destroys dietary thiamine before absorption within the digestive tract. In Lake Michigan, the incidence of EMS rose significantly around 1994 shortly after other invasive species like zebra and quagga mussels (*Dreissena polymorpha* and *bugensis*) or the spiny water flea (*Bythotrephes cederstroemi*) became established. Thiaminase activity in alewife is highly variable in Lake Michigan, which may help explain the year to year variability in EMS. Fry mortality alone does not explain the recruitment difficulties encountered by lake trout (*Salvelinus namaycush*). We have found secondary effect of thiamine deficiency affect swim-up fry more profoundly. Lake trout fry growth, vision, predator avoidance, prey capture and immune function are adversely affected by thiamine deficiency. At times adult mortality may also occur as result of thiamine deficiency. Overall, alewife as predominate forage is an example of food disruption with consequences rippling across the entire ecosystem. Not only are there direct effects (alewife displacement of native species) there are significant impacts on top predators as well. The recent identification of thiaminase in zooplankton may further exacerbate the lack of lake trout survival. Potential source(s) of the thiaminase are unidentified but evidence implicates blue-green algae and/or bacteria.

Do Aquaculture Released Fish Exhibit the Same Life History Patterns in Non-native Environments as They Do at Home? A Case Study of Nile Tilapia, *Oreochromis niloticus*

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We studied the life history of Nile tilapia, *Oreochromis niloticus*, near two aquaculture facilities for two years in coastal wetlands in southeastern Mississippi, U.S.A. Tilapias are known for their plasticity in growth, reproduction, age- and size-at-maturity and feeding that not only make them excellent aquaculture taxa, but also allow them the ability to invade and become established in non-native environments. In 280 collections over 2 years, we represented 29 families, 65 taxa, and 86,415 fishes. Nile tilapia ranked 6th in abundance overall, ranked 2nd among those stations sampled in the Robinson Bayou (inland, low-order stream), and 16th in Simmons Bayou (an estuarine tidal creek). Downstream effluent temperature was always warmer than ambient, and never dropped below 15.1°C. Thus, normal environmental conditions, the presence of the downstream thermal refuge, and the generally low salinity of the bayous of our region all combine to provide a quality environment for released/ escaped fish. Recruitment, reproduction, length-weight relationships, and feeding ecology of this highly invasive cichlid were compared to the same metrics from fish collected in Africa. Males (32.6–30.0 mm TL) and females (31.7–349.0 mm TL) exhibited year-round reproduction with increased intensity in spring (March to May) and in late summer (August to September). Small juveniles (< 25 mm TL) were collected every month except March, and multiple size classes suggest successful recruitment. The smallest female with mature oocytes was 79.9 mm TL, and 50% of the females were mature at 113 mm TL. Batch fecundity (BF) ranged from 30 to 2,603 oocytes for females, whereas relative fecundity ranged from 0.89 to 11.75 oocytes/g EBW. Using PRIMER statistics, Nile tilapia diet was separated from the three native centrarchids based on cluster analysis and nm-MDS. Sequential two-way nested ANOSIM indicted there was no seasonal diet difference (Global R = 0.026), but there was a moderate size class (Global R = 0.457) and a strong species diet difference (Global R = 0.876). Pairwise tests indicated species fed on different components of and locations within the environment, with bluegill, redear sunfish and largemouth bass (all R ≤ 0.683) having the most similar dietary components and Nile tilapia (all R ≥ 0.953) having the most distinct. SIMPER analysis indicated that diets were separated based on prey: bluegill and redear sunfish consumed chironomids and insects; largemouth bass consumed fish and insects; and Nile tilapia fed most often on sediment resources like nematodes, rotifers, bryozoans and hydrozoans. Nile tilapia had the highest frequency of mud, sand and detritus in their stomachs, suggesting they fed directly on bottom sediments. Collectively, these data support our contention that this alien species feeds at the base of the food web, is well adapted to survive, reproduce, and proliferate in non-native environments, and the life history metrics we measured are nearly identical to those reported in the literature from African environments. The philosophy that allows the escape or release of nonindigenous taxa into our present landscape, justified by the belief that species will not survive or become established, is fallible.

Invasion Genetics of Ponto-Caspian Gobies in the Great Lakes and Beyond: Comparisons With Native Populations and Relatives

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Genetic variability, population structure, and evolutionary relationships of nonindigenous versus native populations are compared for the Eurasian round goby *Apollonia (Neogobius) melanostomus* and the freshwater tubenose goby *Proterorhinus semilunaris* (formerly *P. marmoratus*), which are successfully established in the North American Great Lakes and adjoining rivers. Comparisons also are made with other neogobiin taxa, including the racer goby and the monkey goby, which are presently expanding their ranges in Europe and are predicted to invade the Great Lakes. Native population sites sampled include the Black, Azov, and Caspian Seas and most of their primary rivers; ranging from fresh to marine waters. We sequenced the mtDNA cytochrome b and COI genes as well as the nuclear RAG1 gene in order to develop diagnostic genetic characters and to delineate phylogenetic and population relationships from most of the putative 20 taxa comprising the Neogobiin Gobiidae. A wide variety of haplotypes characterize invasive goby populations in both North America and Eurasia, showing high genetic variability in the introductions, and implicating multiple founding sources and no discernable founder effects. Phylogenetic relationships using nuclear and mitochondrial DNA genes are congruent, showing robust resolution for discriminating among taxa and resolving their evolutionary relationships. The molecular markers will allow us to discern new introductions and whether cryptic species are present.

Invasive Gobies in the Middle Danube: What Impact?

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Over the last decade, four species of gobies have invaded the middle stretches of the Danube River: bighead goby *Neogobius kessleri* (Günther, 1861); racer goby *N. gymnotrachelus* (Kessler, 1857); monkey goby *N. fluviatilis* (Pallas, 1814) and round goby *N. melanostomus* (Pallas, 1814). All these species have been reported to spread rapidly, and at least two of them – bighead and round goby – appear to thrive in the Middle Danube area (Hungary, Slovakia, Austria), reaching now upper stretches of the Danube (Germany), too. Indeed, the round goby has several attributes typical for successful invaders, allowing it to establish rapidly in novel environments: increased phenotypic plasticity, tolerance to a wide range of environmental conditions, broad diet, aggressive behaviour, high reproductive capacity, nest guarding by males and a large size compared to species of similar benthic lifestyle. Such massive invasions by alien species may represent a real threat to native fish communities, and the impact of Ponto-Caspian gobies on ecosystem in the Middle Danube could potentially replicate that observed in the Great Lakes of North America. First signs of such impacts have already been observed in two native species that share similar habitats and a part of diet with the *Neogobius* invaders: tubenose goby *Proterorhinus marmoratus* (Pallas, 1814) and common bullhead *Cottus gobio* Linnaeus, 1758. In both species, abundance was observed to decline locally. On the other hand, not always invasive species must have a serious negative impact, necessarily. For example, by now, no alien parasite in the Middle Danube, appearing in association with the goby hosts, has been found. Nevertheless, what will be the impact of the upstream invasion of gobies on the Danube ecosystem remains currently unknown. Over the short history of their invasion, a fluctuation in their abundance has been observed: the earlier abundance leader, bighead goby, was replaced by round goby, which invaded the area later. It has been hypothesized, that certain differences in life history between these two most abundant and closely-related invaders in the Middle Danube area may have important implications for their potential success in novel environments, favouring round goby over short time scales (several years), and bighead goby over the longer term (decades and longer). Naturally, if this hypothesis appears correct, the impact of these invaders on Danubian ecosystem will differ considerably from each other. The hypothesis is further discussed within an epigenetical context, with emphasis on the life history and ontogeny of the two species. This review study is supported by the Slovak Scientific Grant Agency, Project No 1/2341/05.

Present Status of the North American Fish Species, Fathead Minnow *Pimephales promelas* in Flanders (Belgium)

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Although Welcomme (1988) mentions the introduction of *P. promelas* in Belgium in 1983/84 as bait fish (status: reproducing), it was not until 1995 that this species was found in the samples of the Institute for Forestry and Game Management.

Intensive monitoring of fish in Flanders (Belgium) has been going on for more than 10 years now. The institute started its fish monitoring network in 1993. Besides 1500 places where once was sampled, 900 sites on an area of 13512 sq. km (of which 257 sq. km watersurface) are sampled on a regular base (7 year-intervals for standing waters, 5 years for canals and 4 years for running waters), fish are caught by electrofishing, fykes, seine nets and sometimes gill nets.

Until 2004 distribution data were confined to a small area in the R. Demer basin, now more and more data become available about ponds and streams with high density populations of *P. promelas*. Often no other fish are found in these sites where fathead minnows are abundant. Further investigation has to point out

1. What causes the more or less sudden uprise of *P. promelas*.
2. Which are the effects of *P. promelas* on indigenous species.

At least one adverse effect of the introduction of this fish species in Europe has been reported.

The *Yersinia ruckeri* bacteria, which came along with the introduced fathead minnows, infected wild and culture trout and eels and other freshwater fish species and caused 'enteric red mouth disease', which led to serious losses in aquaculture.

Impact of Exotic Fish Species on Native Freshwater Fish Biodiversity of Pakistan

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The total area under freshwater aquaculture is approximately 3 million hectares in Pakistan. A total of 186 freshwater fish species belonging to 83 genera, 26 families and 11 orders have been recorded from Pakistan. For getting higher fish production and biological control of aquatic weeds and mosquitoes, Fisheries department, government of the Punjab, Pakistan introduced exotic species viz. Grass Carp, *Ctenopharyngodon idella* (Valenciennes.), Bighead Carp, *Aristicthyes nobilis* (Oshima) , Silver Carp, *Hypophthalmichthys molitrix* (Valenciennes), Tilapia *Oreochromis niloticus* (Linnaeus.), *Oreochromis aureus* (Steindachner), *Oreochromis mossambicus* (Peters) and Common Carp, *Cyprinus carpio* (Linnaeus). These species substantially alter the physical habitat and created an interspecific competition for space, food and spawning sites. Introductions of exotic species substantially alter the species composition and populations in freshwaters especially where one exotic species or a suite of exotic species come to dominate a community within an ecosystem and changed the biological habitat of the fish diversity that live there, thereby also impair the habitat beneficial uses. Present study also revealed that native fish species viz. *Gibelion catla* (Hamilton) *Labeo calbasu* (Hamiliton) and *Labeo rohita* (Hamilton) declining in natural water bodies.

Silver Carp (*Hypophthalmichthys molitrix*) and Bighead Carp (*H. nobilis*) in the Mississippi River Basin: Occurrence Data and Dispersal Patterns

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Silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*H. nobilis*) are Asian fishes that have become established in the Mississippi River Basin of North America. Because of the potential threat these invaders pose to native aquatic ecosystems, there is interest in determining their dispersal dynamics. We recently used a simple diffusion model as a heuristic tool to gain insight into the dispersion of another aquatic invader, the Rio Grande cichlid (*Herichthys cyanoguttatus*), in southeastern Louisiana. This approach correctly predicted the unexpected occurrence of this freshwater species in estuarine habitats. We attempted to use this approach to better understand the expansion of Asian carp. Occurrence data from fish museums and natural resource managers covering over thirty years of sampling in the Mississippi River Basin and nearby river systems were combined into a geographic information system (GIS) database and used to create yearly distribution maps for each species. Preliminary results suggest that the known occurrence patterns for both species are the result of multiple introductions from different points. It is unlikely that expanding carp populations in the Mississippi River Basin began from a single origin. Also, as we saw with *H. cyanoguttatus* dispersion, Asian carp expansion exhibits periods of apparent stasis during which significant range extensions do not occur. Data suggest that these periods do not reflect an actual slowing of expansion but are artifacts of the limited scope of sampling efforts. While it may be incorrectly assumed that during these periods expansion is limited or has been curtailed, the invaders are likely extending their range "under the radar" of standardized sampling.

An Emergent Infectious Disease Threatens European Fish Biodiversity

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The general result of deliberate biological introduction has been termed the 'Frankenstein Effect' because so many well-intentioned introductions have had unexpected consequences, usually negative. Here we show for the first time that an invasive fish, the Asian cyprinid *Pseudorasbora parva*, acts as a total spawning inhibitor of a native fish, the endangered European cyprinid *Leucaspius delineatus*, and leads to its rapid extinction. This decline is caused by an intracellular eukaryotic parasite, a rosette-like agent that is likely to pose a substantial threat to the conservation of European fish diversity.

Our results have three major biological implications: first that the most invasive fish species in Europe is a healthy host for a deadly, non-specific pathogen that could threaten aquaculture trade, including that of salmonids; second that it is difficult to identify fish populations that are carriers of pathogens; third, that this pathogen could pose a substantial threat to the conservation of European fish diversity although further work is required to confirm this threat.

Habitat Quality of Invasive Nile Tilapia (*Oreochromis niloticus*), Reproductive Behavior, and Interactions With Native Centrarchid Species in Coastal Mississippi

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In coastal Mississippi aquatic systems, Nile tilapia (*Oreochromis niloticus*) has been introduced via aquaculture practices. Tilapias, in general, have been shown to create environmental problems for native species and affect community structure when introduced to new habitats. Nile tilapia is more prevalent in Mississippi than expected even though the introduction is relatively new (~1989). Reproductive habits and the need for bower space of Nile tilapia and native centrarchid species appear to be similar, and competition for spawning space may be a contributing factor in the reduced diversity and abundance of native fishes. Tilapia reproductive leks have been shown to reduce appropriate habitat for native species through direct competition for resources and destruction of habitat. The reduced densities of native species and reproductive success of invasive tilapia species in power plant cooling ponds has also been attributed to possible competition during spawning. We examined reproductive interactions between invasive Nile tilapia and native centrarchids in the clear water of the Plant Daniels cooling pond in Escatawpa, MS. The importance of reproductive behavior on establishment of invasive tilapia was quantified in terms of bower activity in relation to temperature gradient, characteristics of quality nesting habitat, examination of the courtship and breeding behavior, and interactions with conspecifics and native centrarchids during the reproductive season. To date, preliminary data suggested a definite thermal gradient around the cooling pond. Characterization of tilapia bowers incorporated data on location of bowers in the cooling pond, density of bowers, bower morphology, and a sedimentary analysis of the bowers. Twelve quadrats associated with temperature probes placed along the length of Plant Daniels pond were chosen as sites along the shoreline. Bower activity was observed to increase during the fall of 2004, reaching a peak in the late spring of 2005. The bower density patterns were found to occur in a random pattern within a lek, but may be considered clumped around pond itself. Sediment from cores was found to be composed, on average, of fine silty sand, whether it was taken from inside or outside a bower or from either end of the quadrats. Using underwater and aerial videography, as well as bower surveys and ethograms modified from several published sources tilapia and centrarchid aggressive behavior was compared. Nile tilapias were observed to be more directly aggressive toward conspecifics than the native centrarchids and breeding centrarchids were never confirmed, although adults and juveniles were observed throughout the study period. It is possible, based on personal observations, that the native centrarchids moved into the bower habitats after the tilapia reproductive season was ended. For aquatic invasive species, information on numerous biological levels of activity is required to assess if a species will become established and/or expand from the point of introduction, and has direct or indirect impacts. Hopefully this information will contribute to the knowledge and understanding of Nile Tilapia's impact in coastal Mississippi.

Diet Overlap Between Alien Fish Species, Nile Tilapia (*Oreochromis niloticus*), and Native Cyprinid Fish Species (Family Cyprinidae) in Natural Aquatic Environments in Thailand

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Ability to compete for food resources may allow alien fish species to thrive in new aquatic environments and negatively affect local species. Nile tilapia (*Oreochromis niloticus* Linnaeus), a species alien to Thailand, has become feral in many natural waters. To explore feeding relationships between Nile tilapia and native cyprinid fish species (n=3-10 species) in four lakes and reservoirs in Thailand, we evaluated diet composition (%) for each species, frequencies of stomachs containing each food type within each species (% F) as well as diet similarity (non-metric Multi-Dimensional Scaling, MDS) among fish species. The four sampling sites represented major river basins in northeastern and northern Thailand, namely the Mekhong and Chao Praya basins. We sampled fish at the end of the wet (August-October 2003) and dry seasons (May-June 2004) to explore temporal variation in consumption and potential competition.

Most fish examined consumed several types of foods (8 groups). The diet compositions were different among species, sites and seasons ($p<0.05$). Nile tilapia can use a wide range of food types, including both plants and animals. Predominant diets for Nile tilapia were Oligochaetes (average biovolume = 4.2-77%), plant material (average biovolume = 5-26.8%), and plankton (average biovolume = 0.6-26.8%). Phyto- and zooplankton were common diets in all fish species (average % F=96-100). At some sites, Nile tilapia's diet greatly overlapped with some native fish species, such as *Osteochilus melanopleura*, *Osteochilus hasselti* and *Labiobarbus siamensis*. Based on MDS, the degree of diet overlap changed with availability of resources (due to locations and seasons). This study is among the first to generate quantitative data on diet overlap between feral tilapia and native fish species of Thailand. These findings indicate consumption plasticity of each species. Species might only compete for food resources during times of limited resources. Our next step is to conduct experiments comparing food competition of feral tilapia with selected native species (i.e., carps). The resulting data will help us understand food competition in natural aquatic ecosystems.

Exotic Fish Species and Changes in Catch Composition of the Ciénaga Grande de Santa Marta Estuarine System, Northern Colombia

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The estuarine system Ciénaga Grande de Santa Marta (CGSM), Northern Colombia, constitutes the main source of food and income for the regional fishery due to its extension (ca. 1280 km^2) and productivity. Interruption of fresh and marine water inflows, pollution, deforestation, erosion and over-fishing in CGSM led to the loss of valuable resources including ca. 70% of mangrove coverage during the last 40 years. By dredging, in 1998 connections to the sea and the main river were re-established and after that the exotic fish species *Oreochromis niloticus*, *Trichogaster pectoralis* and *Colossoma macropomum* increased their abundance in the CGSM. Since 1999, *O. niloticus* (Nile tilapia) is a commercially important species, accounting for almost 60% of the catches between 1999 and 2000, but dramatically decreasing after 2001 when reopened connections started to fail due to lack of maintenance. This study assesses the changes in catch composition during different periods and determines which of the considered environmental factors (salinity, dissolved oxygen, pH and temperature) are of relevance for a possible control of introduced fish in the CGSM.

Using catch per unit of effort (CPUE) as a relative measure of abundance, the study focuses on the 6 most abundant fish species caught with the most used fishing gear (cast net). The study time was divided into 4 periods: 1) 1994-1995, before reopening the water channels, practically no presence of *O. niloticus*; 2) 1996, higher abundance of Nile tilapia; 3) 1999-2001, a "wet" La Niña event, after reopening the water channels, highest abundance of *O. niloticus*; 4) 2001-2003, water connections obstructed, abundance of Nile tilapia dramatically decreased.

Multivariate techniques were used to identify patterns of change in catch composition among periods. Multiple regression analysis was used to determine which environmental variables relate the best with the introduced fish and the 6 most abundant native ones.

Catch composition of native fish has changed accordingly to the environmental changes but kept approximately the same proportion of overall CPUE during the fourth periods. Salinity is the most critical parameter controlling the abundance of fish species. Low salinities favoured high abundances of exotic fish. Significant correlations between the abundances of native and exotic fish could be better explained by their joint correlation to environmental variables.

Large fluctuations in fresh water versus marine water influx greatly regulate the abundance of *O. niloticus*, which is not well adapted to the big environmental changes in the CGSM. Even though the exotic fish did not prove to directly affect the native fish abundances in a negative way, management measures should be taken to avoid such effects when water connections start functioning properly and conditions could favor a longer period of permanency of the exotic fish in CGSM. Controlling salinity through the input from water connections in the estuary can keep low abundances of *O. niloticus*, but further experimentation is needed to establish the salinity threshold for native and exotic fish in the system.

Non-native Freshwater Plants in Ireland

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The number of non-native freshwater macrophytes species recorded in Irish watercourses has increased significantly since 1990. Serious concern has been expressed among a broad range of interest groups because of the potential adverse ecological, economic and social consequences that can attend the presence of such species. However, it should be acknowledged that not all non-native species are invasive and that current problems are caused by only a small percentage of those plants that have been introduced into the country. Whether or not an introduced plant will become a true invasive is influenced by a number of factors. These include the number of propagules that the species is capable of releasing into the new habitat, the biological traits of the introduced species, the competitive abilities of the indigenous species, and the susceptibility of the habitat to invasion. The presence of a truly invasive species is evidenced by an unexpectedly rapid biomass expansion and a demonstrable adverse impact on native communities. A number of non-native freshwater macrophytes have recently been listed as potentially high impact species by the Environment Protection Agency in Ireland as part of their Alien Species Risk Assessment. These include *Crassula helmsii*, *Elodea nuttallii*, *Azolla filiculoides*, *Hydrocotyle ranunculoides* and *Myriophyllum aquaticum*. These are species that are currently deemed to pose a significant risk to Irish native community diversity. Another aquatic plant, *Lagarosiphon major*, was not included in the list but is now considered to represent a significant potential risk to the environment.

During 2005 two invasive species, *L. major* and *E. nuttallii*, came to particular prominence in Irish watercourses. Where they were recorded both expressed themselves as true invasives by producing virtual plant monocultures, by rapidly expanding their range within the affected habitat and by displacing indigenous plant species and communities. Furthermore, their presence significantly impacted amenity usage of the infested waterbodies. The paper presents case studies for these two species. The recent distribution of the species in Ireland, the adverse impacts that each has already had on the native biota, and the potential ecological, economic and social risks associated with each is described. The biological traits that confer the obvious competitive advantage on these invasives are also explored. The need for comprehensive and enforceable legislation, a clear and concise education and awareness programme, and a workable suite of efficient, environmentally sensitive and cost effective control methods to prevent the entry of invasives into the country and their spread within the country is discussed.

Rapid Response Planning Efforts for Aquatic Invaders in Massachusetts

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Aquatic invasive species have become a critical issue in coastal resource management. The Massachusetts Office of Coastal Zone Management (CZM) has taken a lead role in aquatic invasive species management in the region and is working closely with partners in the Northeast to minimize harmful effects from these introductions.

The prevention of new introductions is the most effective way to minimize impacts from introduced species. However, if prevention fails, managers must have a means of quickly responding to an invader before it becomes established. Early Detection and

Rapid Response (EDRR) planning has been identified as a management priority for Massachusetts and the Northeast region. In May of 2003, CZM and the Northeast Aquatic Nuisance Species Panel (the NEANS Panel) held an Early Detection and Rapid Response Planning Workshop at which participants identified the fundamental elements of a model rapid response protocol. The current project builds on the foundations laid by this workshop and will further refine the model rapid response plan and develop some of the resources necessary for implementation. The project focuses on Massachusetts as a pilot for the region. Once Massachusetts EDRR planning is refined, the products will be transferable to the other states and regions. Objectives of this plan include:

1. Establishing a bioinvasion reporting and verification network
2. Developing a risk assessment protocol for potential new invaders
3. Developing an advisory list of rapid response trigger species
4. Developing generic and species-specific rapid response plans

To date, a great deal of progress has been made towards EDRR planning in Massachusetts. The fundamentals of a reporting network have been created with an acting advisory council to take leadership in planning efforts. A directory of taxonomic experts is also available. Criteria for assessing the risk of potential aquatic invaders have also been established. Currently, the focus of the project is a demonstration rapid response to a relatively new invasion. The Chinese Mystery Snail (*Bellamya chinensis*) was recently discovered in a pond in Groveland, MA. A plan is being developed to respond to the new infestation, including recommendations for hand removal of the snail as a means of control and eradication. Volunteers will be assisting in the control project. A preliminary removal was performed at the site on October 15, 2005. Plans are being coordinated for several more removal days in the summer of 2006. A mark-and-recapture methodology will test the effectiveness of removal on the snail population. The generic EDRR protocol may be modified based on the outcome of the demonstration project.

The ultimate goal of the project is to produce a web-based resource that will allow managers to quickly and effectively respond to new marine invaders. This plan will serve as a model rapid response protocol for marine invaders that will be transferable to other states and regions.

Ready, Set, Go – Applying Spill Response Lessons to AIS Rapid Response Planning

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After prevention, rapid efforts to eradicate incipient populations of aquatic invasive species (AIS) offer the best hope to avoid long-term impacts from an introduction. Many state, regional, and national groups are investing in development of rapid response plans to improve their capacity to act quickly to new AIS introductions. Although there are a handful of successful rapid response stories to guide such efforts, AIS managers can also benefit from many lessons derived from the parallel realm of oil and hazardous material spill response. Particularly since the *Exxon Valdez* spill in 1989, a multitude of spill contingency plans and other response preparedness tools have emerged. Spill response planning concepts and methods that can greatly benefit AIS rapid response include:

- *Cascading contingency plans:* localized (perhaps species-specific) plans nested in more general regional plans that fall under the framework of a broad national plan;
- *Caches of equipment:* Response resources that are strategically situated and available rapidly for deployment;
- *Unified Command System:* an organized structure for clarifying and staffing key roles and responsibilities;
- *Effective communication systems*: use of emergency call-down lists, toll-free reporting hotlines, and centralized command centers;
- *Response Trust Funds:* dedicated funding pools available to federal or state lead agencies to pay for immediate expenses (particularly for AIS introductions, where there are typically not opportunities to obtain funding from a potentially liable party);
- *Scenario-based planning:* Developing plans based on specific situations, ranging from relatively simple cases (e.g., an isolated pond) to "worst case" scenarios;
- *Drills and exercises:* Periodic tests of notification processes, equipment availability, etc.

These and other spill response planning measures were developed given the potentially disastrous consequences of delayed response to a major oil or chemical spill. Given that AIS "spills" also involve the species' ability to spread via reproduction, it is that much more critical to apply similar measures and resources to rapid response planning for biological invasions.

Keeping a Regular Watch for Marine Pests: A Quality-assured Monitoring Program for Australia and New Zealand

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Comprehensive baseline surveys have been carried out in ports around Australia and New Zealand (protocols for baseline surveys are described in Hewitt & Martin 1996, 2001). These surveys provided a snapshot of each country's marine pest status providing comprehensive data on the presence/absence of a large number of species in each surveyed location. Australia and New Zealand have recognised the importance of more regular and ongoing monitoring for marine pests in order for countries to protect their waters from marine pest risks. Working collaboratively we have designed a species targeted ongoing monitoring strategy that will form an integral part of Australia's National System for the Prevention and Management of Marine Pest Incursions (Australian National System) and New Zealand's marine biosecurity system.

The monitoring strategy aims to detect new marine pest incursions (pre-border failure) as well as secondary introductions or translocations of established marine pests (post-border failure). The strategy will support the prevention, emergency response and ongoing management elements of both countries' marine pest management programs. Monitoring results will help guide management actions to: trigger emergency response actions; make decisions on management and control programs for established marine pest populations; review and improve measures that form part of the Australian National System and the New Zealand's marine biosecurity system; and inform broader policy decision on marine pest management.

The ongoing monitoring approach is not intended to replicate previous baseline surveys. Considering the need for regular and cost effective monitoring, the monitoring approach is "species and location targeted" and focuses effort on likely invasive marine species and likely locations for a marine pest incursion. The ongoing monitoring approach will only collect presence/absence species data and not abundance data.

Australia and New Zealand have developed a set of standard, quality-assured quality-controlled (QAQC) procedures for marine pest monitoring and decision-making to ensure monitoring data is collected using rigorous, consistent methods. While the rationale for site and species selection for the targeted approach has been previously explored, development and agreement of QAQC requirements for monitoring is in its infancy. QAQC requirements and procedures will be agreed for: choosing species to monitor; spatial and temporal selection of sites; selecting observation/sampling methods that work best for the target species; reporting and review; and stakeholder engagement.

To assist in designing and implementing monitoring programs that meet the agreed minimum QAQC requirements, Australia and New Zealand will publish a marine pest monitoring manual. This manual will provide clear instructions for all aspects of monitoring strategy including: designing monitoring programs; selecting appropriate observation/sampling methods; sample collection and analysis; verification of results; and reporting results. The monitoring manual will be e-published in late 2006.

Ontario's Response to Detection of Round Goby (*Neogobius melanostomus*) in a Tributary of Lake Simcoe: An Eradication Case Study

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Lake Simcoe is the largest inland lake in southern Ontario, Canada, and the province's most popular tourist destination for U.S. yellow perch anglers. Its vibrant recreational fishery is very important to the local and regional economies with an estimated value of $200 million dollars annually.

Round goby (*Neogobius melanostomus*) were confirmed in Pefferlaw Brook, a tributary of Lake Simcoe in July 2004. No natural or man-made structures existed in the brook to prevent goby from spreading to Lake Simcoe. The Ontario Ministry of Natural Resources coordinated support from other provincial and federal agencies as well as non-government groups to undertake an aggressive surveillance program to determine goby distribution in Pefferlaw Brook, Lake Simcoe and other tributaries. While options to prevent the spread of round goby into Lake Simcoe were investigated, monitoring documented the continued downstream spread of goby toward Lake Simcoe. Consideration of feasible options, given the known distribution of goby in the system, lead to the decision to treat a 5 km section of the brook with a piscicide to attempt eradication of round goby before they became established in Lake Simcoe. The approach taken by Ontario will be discussed including follow-up monitoring and assessment of project success.

Managing the Invasive Alien Molluscs, *Pomacea* spp.: A Global Perspective

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Golden apple snail (GAS), *Pomacea* spp. – a freshwater invasive alien species is the best-documented example of introduction from South America into tropical Asian wetland ecosystems, in the early 1980s as a high protein food source that continues to have serious implications on economy and ecology. GAS invasions endanger food production, living environment, ecosystems, and public health. Estimated losses from GAS to rice crops during the 1980s is of USD $1 billion globally, while in the Philippines alone it is between USD $425-1,200 million, excluding non-market damages to public health, native biodiversity, and aquatic ecosystems. The paper outlines the global perspective of GAS invasions to mitigate its multiple impacts by facilitating exchange of information and expertise, and increase awareness in the wider community about biodiversity impacts. Finally, I will discuss the development of an improved ecologically sustainable management strategy at the national, regional and global level.

Applesnail (*Pomacea canaliculata*-complex): Distribution, Density, Population Dynamics in Southeastern Texas and Potential Threat to the Rice Industry and Coastal Ecosystems

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South American channeled applesnail (*Pomacea canaliculata*) and related species (*P. canaliculata*-complex) have been introduced throughout the Indo-Pacific Region where they have become a major threat to rice and taro crops. By mid 2005, applesnails had been found in several mainland U.S. states including Alabama, Arizona, California, Georgia, Florida, and Texas. These U.S. introductions were most probably related to releases and escapes from aquarium and pet trade sources. Taxonomic identification of these snails is problematic. Genetic analyses have shown that specimens from Texas belong to *P. canaliculata*-complex, but are not true *P. canaliculata*. In Texas, living snails were first reported in 1989. A survey of applesnail distribution in summer 2005 confirmed their presence in 6 southeastern counties (Harris, Chambers, Brazoria, Galveston, Fort Bend, and Waller). Applesnails were found in 17 waterways, including 4 discovered outside of their previously known range. Density of snails in streams, ponds, and a rice field were usually low, from < 1 to 4 snails/m^2, but could be as high as 44 snails/m^2. Studies of population dynamics (density, size structure, and reproduction) are ongoing at several lentic and lotic ecosystems in southeastern Texas. Reproduction of snails in Texas starts in early March and continues to late October – early November. Thirteen species of wetland and aquatic plants were tested in laboratory feeding experiments to determine the possible snail damage to coastal ecosystems. No significant applesnail damage to natural ecosystems or rice crops in Texas has been reported to date. Possible reasons for lack of impact in Texas compared to that in the Indo-Pacific could be different invasion history, snail densities, and rice growing technology, among others. Potential future impact to coastal ecosystems and the rice industry in the continental U.S. will be discussed.

Applesnail (*Pomacea canaliculata*-complex): Distribution, Projected Spread And Population Dynamics on the Texas Gulf Coast

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The channeled applesnail (*Pomacea canaliculata*) is an exotic invasive species that has been a significant pest for agricultural crops and native macrophytes in many countries in Southeast Asia. Related species (*P. canaliculata*-complex) are present in the United States in Hawaii and six continental states. Living *Pomacea canaliculata*-complex snails were first found along the Rice Belt of the Texas Gulf Coast in 1989 and again in 2000. The potential for damage to crops and native vegetation from these introductions in Texas could be devastating. A one-year study of applesnail population dynamics, current distribution, size structure, densities and trapping methodology was conducted in southeastern Texas in several lentic and lotic ecosystems. Average snail densities were different among sampling sites, with a maximum-recorded density of 44 snails/m^2 and biomass of 30.4 kg/m^2 found in ponds. During summer 2005, 314 sites on the Upper Texas Gulf Coast were surveyed for presence of snails; 44 of these sites were found to have snail populations. As of August 2005, snails were found in 17 waterways and their tributaries, including the American Canal, Buffalo Bayou, Oyster Creek, Armand Bayou, Dickinson Bayou, Mustang Bayou, New Bayou, Bear Creek and Clear Creek. Densities and biomass of snails in infested waterways were lower than in ponds, with the highest density of 24 snails/m^2 and biomass of 1.4 kg/m^2 found in the Mustang Bayou watershed. Data of abiotic and biotic parameters of sampled sites were collected, and will be combined with presence/absence data to predict the future spread of applesnails using GIS mapping technology.

Applesnail (*Pomacea canaliculata*-complex): Feeding Selectivity, Reproductive Potential and Environmental Impact on Southeastern Texas Ecosystems

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Applesnails of the *Pomacea canaliculata*-complex are aquatic invasive species native to South America that have the potential to harm aquatic ecosystems and agricultural crops at some introduction sites in USA. These snails are currently found in six counties in southeastern Texas (Harris, Chambers, Brazoria, Galveston, Fort Bend, and Waller). Wetland restoration efforts in the area prompted concern regarding the feeding habits of this voracious aquatic pest. Snail feeding selectivity and extent of plant consumption of wetland macrophyte species, as well as feeding activity of different size groups were monitored in the laboratory. Important wetland macrophytes tested were: *Canna glauca, Ceratophyllum demersum, Hynenocallis liriosme, Panicum hemitomon, Pontedaria cordata, Ruppia maritima, Sagittaria graminea, Sagittaria lancifolia, Scirpus californicus, Scirpus maritimus, Spartina alterniflora, Thalia dealbata,* and *Typha latifolia.* Notable feeding preference was found among the tested plant species. Reproductive potential of applesnails in Texas will be estimated based on field and laboratory studies. The results of the study will be used to estimate the potential environmental impact of applesnails on ecosystems in southeastern Texas.

Feeding Preference and Consumption Rates of Aquatic Vegetation by the Channeled Apple Snail

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The channeled apple snail (*Pomacea canaliculata* Lamarck) is an exotic invertebrate species that poses a significant threat to wetlands and bodies of water throughout Florida and the United States. The channeled apple snail is native to South and Central America and was most likely introduced into the continental United States through the aquarium trade. The channeled apple snail is a voracious herbivore and has been introduced to other parts of the world as a biocontrol measure for aquatic weeds; however, the species appears to be a non-specific feeder and often consumes aquatic crop plants (e.g., rice, taro) and desirable native plants as well. If the channeled apple snail indiscriminately consumes all flora, the consequences to Florida's ecosystem could be devastating. Little research has been conducted to investigate the feeding habits and preferences of the channeled apple snail; therefore, the objective of this research was to determine if this exotic snail is truly a non-specific feeder or if the snail shows a feeding preference when presented with an assortment of submerged aquatic species.

Submerged plant species used in this study included *Najas* sp., *Myriophyllum aquaticum, Potamogeton illinoensis, Chara* sp., *Egeria densa, Vallisneria americana* and *Hydrilla verticillata*. This experiment was a 2 x 7 x 4 factorial with 2 treatments (snails vs. control), 7 plant species and 4 time intervals. Four replicates (tanks) were used for each treatment combination, with random placement of control and snail tanks and random placement of plants within tanks. Harvested plant shoot material was weighed and data were analyzed to detect differences between treated and control plants of the same species (LSD) and differences among plant species (t-test) harvested at a given time interval. Preliminary trials indicated that the channeled apple snail strongly preferred *Hydrilla, Najas* and *Chara* and avoided *Egeria* and *Myriophyllum*. The results of this experiment will be discussed and will provide additional information regarding the feeding habits and preferences of the channeled apple snail. In addition to these feeding preference data, optimum feeding temperature ranges and food consumption rates (mg of plants consumed per mg of snail body weight) will be reported.

Genetic Characterization of Invasive Apple Snail Populations in the Continental United States

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While there is only a single native apple snail in the United States, the Florida apple snail *Pomacea paludosa* (Family Ampullariidae), the non-indigenous ampullariids *Marisa cornuarietis* and *Pomacea bridgesii* have been present in Florida for many decades. More recently, however, non-indigenous apple snails, referred to informally as "channeled apple snails" or "golden apple snails", have been appearing with increasing frequency in the continental United States. Given the dramatic effects that channeled apple snails have had on both natural and agricultural areas in SE Asia, their introduction here is a cause for concern, particularly in ecologically sensitive areas, such as Everglades National Park and Loxahatchee National Wildlife Refuge. Plans for management and control of these snails, and attempts to determine source populations and pathways of introduction into the U.S., have been hampered by widespread taxonomic confusion concerning the number of species present and their identities. This confusion is a consequence of the conservative external morphology and phenotypic plasticity of species within this group. Here, we have taken a genetic approach to help clarify the identity and distribution of apple snails of the *Pomacea canaliculata* group in the continental U.S.

We have examined snails from many locations spanning five states (Florida, Georgia, Texas, California, and Arizona). These samples were supplemented with museum collections and new native range collections in South America. We examined mitochondrial and nuclear gene sequences, and analyzed these phylogenetically to determine the number of genetically-distinct lineages and their distributions within the U.S. Based on our sampling to date, it appears that true *Pomacea canaliculata* is not common in the continental U.S., being restricted to California. Instead, the majority of populations in the continental U.S. appear to be a species closely related to *P. canaliculata*, whose name awaits resolution of some taxonomic inquiries. A third species, which has bright green egg masses, appears to be limited in its distribution to south Florida. Our results suggest that measures should be taken to prevent the spread of true *Pomacea canaliculata* from California to other states. Further clarification of species identities will allow us to access what is known about the factors that control the distribution and abundance of these species over their native range. This should prove valuable in developing management and control strategies. In addition, an understanding of the native range of these species may help us to estimate the range likely to be achieved by these species in the areas where they have been introduced. Additional topics that require exploration include the possibility of hybridization between native and introduced ampullariids, leading to detrimental effects on native populations, and hybridization among exotic species, which may result in novel, potentially more invasive genotypes. The parasite complement of the introduced species should also be characterized.

The Tale of Two Snails: Comparing and Contrasting the Ecological Roles of a Natural Versus Exotic Population of *Pomacea*

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The imperceptible progression of invasion biology and the serendipitous events that promote spread often lead to studies that can only address the impacts of an exotic species on its environment after establishment has occurred. Too often, exotic species lurk under our radar until a population reaches some threshold that captures our attention and subsequently triggers a cascade of studies. For many organisms, especially invertebrates, few studies exist that rigorously test the potential mechanisms that may account for ecological patterns we see in nature. However, in some ways, the need for experimentation and rigorous statistical analyses can also overshadow the importance of any insight gained from simple observations of an organism's natural history and its ecological role in the habitat. The increasing number of detrimental exotic invertebrates as successful invaders advocates the need for any information that might aid in management efforts of new species and potentially alleviate future ecological and economic costs.

Investigations that couple experimentation with natural observations may be best suited to lend insight into what characteristics may lend invasive success to exotic populations or what mechanisms control native populations. Our on-going work compares and contrasts common life history characteristics between two populations of *Pomacea*, an exotic population in southeastern Texas (Armand Bayou) and a native population in Maldonado, Uruguay. Data from the Texas population will include snails and eggs collected between April 2005 and April 2006 while we collected Uruguay snails and eggs only during early summer in Uruguay (December 2005). Our two study groups represent the taxa that one is most likely to encounter within those geographical regions. While the species identity of each of these applesnail populations remains uncertain and still under genetic analysis, striking patterns appear that potentially suggest alternative ecological roles and contrasting impacts of the populations on their respective habitats. For each population, we investigated life history characteristics of eggs and hatchlings, size relationships of adults, feeding preferences of adult and juvenile snails between whole plants and reconstituted plants (i.e., chopped, dried, freeze-dried, powdered and then placed into a paste with sodium alginate), and preferences in oviposition location by females. In addition, for the Uruguayan population, we collected empty carapaces in areas dominated by two avian specialist predators to test for the presence of size-selective predation of the native species.

Pomacea from Uruguay laid far fewer eggs per clutch than those in Texas. Furthermore, we found a much stronger relationship between clutch mass and egg number in the Uruguayan population, suggesting higher variability in clutch size in the exotic population. In addition, we discovered a very strong logistical relationship between snail mass and operculum size for the Uruguayan population, providing a clear maximum size below what we find in the Texas population. Large, adult snails dominate the Texas where the population seems to lack a diverse age structure. In terms of hatching, the vast majority of eggs from the native population hatched successfully, while hatching efficiency of clutches from Texas varied considerably. In the Texas population, we did not find any relationship between incubation time and hatchling size, instead clearly determining a threshold hatching size of 1.1 mm. We expect to find larger-sized individuals hatching from the Uruguayan clutches compared to those in Texas and also hope to be able to compare growth rates.

Our observations of clutch position in Armand Bayou (Texas) suggest that snails tend to lay eggs on any hard surface, although perhaps favoring elephant ear (*Colocasia esculenta*). In Uruguayan wetlands that largely lacked any woody vegetation or artificial structures, *Pomacea* showed an oviposition preference for *Schoenoplectus californicus* over *Echinodorus grandiflorus* and laid significantly more clutches closer to the shoreline. In terms of vulnerability to predation, we found that carapaces with holes possessed slightly smaller operculum widths than intact shells, perhaps indicating differential susceptibility of the native population to avian predators. In terms of feeding preferences, reconstituted plants (*Myrophyllum spicatum* and *Eichhornia crassipes*) combined with chemical extracts repelled feeding by both populations. *Pomacea* from Uruguay showed higher rates of consumption of reconstituted food, although also notable consumption of whole plants besides *Eichhornia*. Juvenile snails tended to consume more resource per body size than adults.

Collectively, our observations and experiments with these two populations suggest that *Pomacea* from Uruguay function primarily as grazers and may be limited in size and number by avian predation. In contrast, larger clutch sizes, lack of predation, and generalist feeding responses of the exotic *Pomacea* in Texas fail to suggest any limits to their invasive potential.

Design and Implementation of Shipboard Tests of Ballast Water Treatment: The Case of Venturi Oxygen Stripping (VOS)

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Transport of non-native aquatic species via ballast water uptake and discharge is a key vector of invasion. To address this problem, the IMO has set discharge standards of less than 10 viable organisms/m^3 >50-µm in size, less than 10 viable organisms/ml between 10 and 50-µm, and specific limits for indicator microbes. In many cases, only extreme reduction of ballast-entrained plankton (four or five orders of magnitude) can meet these standards and the USA is contemplating even more rigorous limits. Consequently, effective onboard ballast treatment must be developed, evaluated and employed. Ship board treatment systems are indeed appearing, along with test programs aimed at regulatory validation and industry acceptance. Typically, industry builds a prototype, and academia is tasked to provide objective performance data. In fact, evaluation of full-scale treatment system performance onboard ships during routine operations will be required by the IMO and other regulatory agencies.

Various evaluation approaches have been used specific to a platform (ship), geographic location (environmental conditions), route (voyage duration and operating conditions), and suite of performance measures (biological response variables). The growing number of approaches makes comparisons across technologies (and sometimes within the same technology evaluated by different groups) difficult.

Scientists and regulators attending a meeting in Portland, OR, in June 2005, worked to establish standardized evaluation criteria in three main areas:

- Basic research on the performance (effects) of ballast practices and technologies;
- Tests to approve the use of specific practices and technologies;
- Tests to determine compliance with regulatory requirements.

We will discuss the approach we used to evaluate the VOS treatment system and how it compares with conclusions produced at the Portland meeting. VOS works by creating hypoxic (<1-mg/l) and CO_2 saturated (with lowered pH) ballast water. VOS achieved the IMO standard in pilot-scale mesocosm tests and preliminary shipboard tests after holding times of 4 days. However, the ship was not modified to allow sampling of the intake or discharge streams, where IMO specifies allowable plankton density. Rather, final sampling was performed within tanks several hours before deballasting. Sampling discharges would be ideal but few if any existing vessels provide facilities for this. The VOS tests used zooplankton, phytoplankton, and microbes as quantitative indicators of treatment effectiveness. We employed live and dead counts of zooplankton, and grow-out plus fixed total cell counts of phytoplankton, and fixed total cell counts plus chromogenic specific substrate, most probable number analysis for specific bacteria. Treated and untreated tanks undergo side-by-side comparison.

There is a clear need for standardizing ballast water treatment evaluation approaches, particularly onboard vessels. Lack of standardization results in lost opportunity to increase the cumulative (comparative) value of on-going studies, creates significant confusion about criteria for evaluation and approaches to be used to determine compliance with regulatory requirements, and can hinder the development and approval of treatment systems.

Performance Monitoring of a Biological Deoxygenation Process to Treat Ballast Water

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Biological deoxygenation may offer an effective method to treat ballast waters by generating hypoxic (<1 mg/L) conditions within a few hours. In order to assess the effectiveness of the treatment, it is recommended that the performance of the biological reactor should be monitored on-board. Standard microscopic analyses based on colorimetric determinations for such on-board monitoring are time-consuming, require much manipulation and can be subjected to high variability among manipulators. The objective of our study was to test and validate the use of UV spectrophotometry and flow cytometry for rapid and quantitative assessment of the bioreactive deoxygenation treatment. Results from laboratory experiments show that the profiles of the UV-spectrum ranging between 190 and 280 nm may provide a rapid assessment of the behaviour and performance of the bioreactor over time, by quantifying the relative number of live and dead cells in treated waters. Analyses by flow cytometry also permit to discriminate between viable and no-viable organisms and provide an index of the treatment effectiveness. Results indicate that biological deoxygenation causing anoxic conditions may significantly decrease and eliminate phytoplankton biomass in treatment tanks. Given that small and robust UV-spectrophotometer and flow cytometers are commercially available, the direct monitoring of the performance and effectiveness of the biological deoxygenation treatment on-board ships is now possible.

Treatment of Ballast Water Organisms Using High-power Ultrasound

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Proposed or developing regulations set discharge standards on ballast water that will require the use of treatment systems rather than existing management options such as ballast water exchange. Ultrasound is a candidate treatment approach for ballast water; however, current ultrasonic treatment systems do not meet the projected discharge standards, and their operational costs are unacceptably high. New magnetostrictive materials such as TERFENOL-D may provide the basis for more cost-effective treatment systems, utilizing either ultrasound alone or in combination with other technologies. TERFENOL-D is a 'giant' magnetostrictive alloy that is more robust and can generate higher energy densities than the piezoceramic materials typically employed in ultrasonic treatment systems. We are investigating the performance of TERFENOL-D based ultrasonic treatment systems at the benchtop and pilot scales. Results from a benchtop-scale system indicated that treatment of bacteria required contact times on the order of 1 to 10 minutes to generate 90% mortality. In contrast, 90% of zooplankton could be killed at contact times of 3 to 9 seconds. Initial experiments utilizing a pilot-scale (25 gpm, 20 psi) system suggested important interactions between flow rate and pressure affected mortality of zooplankton by ultrasound. Mortality rates of *Artemia* in the pilot-scale system were higher than in the benchtop-scale system. We are currently testing for synergistic effects on mortality of zooplankton and bacteria between ultrasound and heat treatment, and ultrasound and chlorination.

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Tests of a Ballast Water Treatment System Onboard an Ocean-going Vessel: The OceanSaver Approach

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A new ballast water treatment system was tested in full scale experiments onboard of two vessels since spring 2005. This OceanSaver treatment system comprises of three steps, i.e., filtration, nitrogen injection and cavitation. System tests have been undertaken according to the relevant IMO Guidelines. The system will be described and results of the first treatment trials onboard will be presented.

M.V. *Federal Welland* / OceanSaver Ballast Water Treatment Project

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At the 11th and 13th International Conferences, I described Fednav's responses to various U.S. and Canadian state, provincial, and federal ballast water initiatives in the Great Lakes. Those presentations centred on the concern we had with the possibility of multiple and potentially conflicting legislative initiatives impeding shipping in the Great Lakes and the effort that Fednav undertook to help craft acceptable ballast water legislation in the State of Michigan in 2001 and its endorsement thereof by offering its vessel, the *Federal Yukon*, as a platform for the testing of two biocide ballast water treatment technologies that were tested, albeit with inconclusive results, by the Michigan Department of Environmental Quality.

A lot has happened since my two earlier presentations, both in the increased attention given to the ballast water/aquatic invasive species issue in the Great Lakes and, more importantly, the efforts the shipping industry and, in particular, Fednav have taken to respond to the acknowledged need to find an acceptable and effective alternative to deep sea ballast exchange in treating vessels' ballast water. The adoption by the International Maritime Organisation of the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* in February, 2004, and the inclusion in that Convention of biologically defensible standards for the treatment of ballast water have encouraged, as was expected, a number of companies to accelerate the research into and development of promising on board ballast water treatment technologies. Among those is the Norwegian company MetaFil AS and its OceanSaver Ballast Water Treatment System under development in Norway since 2002 and which has advanced to the point that a prototype of the OceanSaver System has been retrofitted on Leif Hoegh's car carrier *Hoegh Trooper* in April, 2005, and on Fednav's Seaway-size bulk carrier *Federal Welland* in September, 2005.

The OceanSaver System, which comprises three components in treating ballast water as it is taken on board and discharged, including 50 micron filtration, deprivation of oxygen through nitrogen super-saturation, and, the key to the System, hydro-dynamic cavitation, initially caught Fednav's attention because of Det Norske Veritas', the classification society for the majority of its fleet, association with that System. Furthermore, Fednav's consideration of the merits of the OceanSaver System included its added advantage in prolonging the integrity and life of ships' ballast tanks and their coatings by removing oxygen from those tanks and the credibility and experience of the people, companies, and universities participating in the research and development behind the OceanSaver System. In February of 2005 Fednav not only committed to purchase a prototype of the OceanSaver System but was sufficiently convinced that the System would prove to be effective that it made a significant investment in MetaFil.

When this presentation is made in May, 2006, the first two components of the OceanSaver System will have been installed and operating on board the *Federal Welland* since September, 2005, and DNV's analysis of the testing of those two components' effectiveness in achieving, and hopefully surpassing, the standards prescribed in the IMO Convention, will have commenced. Development of the third and key component, the C3 hydro-dynamic cavitation, is not expected to be completed until mid-2006 at which point it will be integrated with the first two components of the OceanSaver System on board the *Federal Welland*. While it is acknowledged that we will not know how effective the OceanSaver System is in eliminating bacteria until the C3 component is included, it is, nevertheless, my intention to share with the Conference's participants the initial test results of the first two components of OceanSaver prototype on board the *Federal Welland*.

Effectiveness and Toxicological Impact of Two Ballast Water Treatment Methods at Very Cold Water Conditions

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Alternative methods proposed to treat ballast waters must be effective over a large of salinity and temperature and must environmentally to the receiving environment. We tested the effectiveness and the potential toxicological impact of a biological deoxygenation process and the Peraclean Ocean peracetic acid formulation, to treat ballast waters at very cold temperature. Experiments were conducted in large-volume (4 m^3) tanks filled with unfiltered freshwater from the St. Lawrence River and maintained at temperature between 0.6 and 1.9°C. Water quality parameters were monitored daily during the experiments and the toxic responses from 6 ecotoxicological assays were determined at three different times. Results showed that hypoxic conditions (<0.5 mg/L) from the biological deoxygenation process were achieved over the entire water depth in large containers in 10 days and resulted in significant reduction in phytoplankton biomass in the treated tanks. Treated waters were found to be toxic to a wide variety of organisms, from bacteria to fish, but residual toxicity decreased over time and became undetected at the time of discharge. Experiments with the Peraclean Ocean indicated a rapid decline in levels of peracetic acid within the first 48 h after treatment but levels of hydrogen peroxide remained relatively stable. The addition of catalase quickly and effectively eliminated hydrogen peroxide residues indicating that the enzymatic reaction can proceed at very low water temperature. The dose-response curves of the Peraclean Ocean treatment were very steep in all toxicological assays indicating a very sensitive toxic response. The living biomass of microorganisms was significantly reduced in treated tanks. It is concluded that both treatment methods can effectively treat ballast waters under a wide range of temperature and salinity conditions, including very cold water conditions as typically encountered in Canadian waters during the winter and in Arctic waters.

Carbon Dioxide as a Biocide for Ship Ballast Water: Some Experimental Results

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A growing body of research has shown that elevated concentrations of dissolved CO_2 can be deleterious to marine organisms. Such effects are relevant in anticipating the environmental impacts of the ongoing increase in atmospheric and (via air-sea equilibration) ocean CO_2 concentrations. The impact of elevated CO_2 is also pertinent to CO_2 mitigation proposals that call for the ocean to be used to store molecular CO_2 that has been captured from industrial and power generation processes. In addition to lowering seawater pH through the formation of carbonic acid, elevated CO_2 also can affect biota in ways unrelated to acidity alone. This is evident by observations of significantly enhanced lethality of a given pH lowered by CO_2 addition relative to the biotic effect of the same pH attained by mineral acid addition. In addition to its biocidal properties, CO_2 is readily available as a commercial or waste product of fossil fuel combustion, and on exposure to air, excess dissolved CO_2 quickly dissipates from water once input is stopped. Given these features we ask: can this gas be used as a cost-effective, readily-reversible, environmentally safe treatment for removing invasive species from ballast water?

To address this question we incubated in darkness 200L containers of seawater, containing known concentrations of zooplankton and microbes, aerated with ambient, 1%, or 10% CO_2 gas/air levels. During five days of treatment we observed on average a >96% removal of viable zooplankton (>73 mm) in the 10% CO_2 treatments. Viable zooplankton numbers remained at these low levels for 7 days after the CO_2 treatments were ended implying a significant, long-term impact to the resident community. In contrast, the 1% CO_2 treatments were much less effective in removing zooplankton, and significant population growth was evident 7 days after termination of gas treatment. Differences in response to CO_2 addition were observed among zooplankton taxa. Significant reduction in microbial abundance and activity was not evident in any treatment.

We will further discuss our recent experimental results addressing i) the optimal concentration of CO_2 necessary to meet IMO criteria, and ii) possible synergistic biocidal effects of combining CO_2 addition with other treatment technologies.

Two Shipboard Demonstrations of Chlorine Dioxide to Control AIS: Swedish Flagged Ro-Ro/Container and U.S. Flagged ITB Bulker

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Chlorine dioxide has a 50 plus year history of safely and economically controlling microorganisms in industrial and municipal applications. Chlorine dioxide is unique in its effectiveness against all organisms. Chlorine dioxide does not form unwanted chlorinated by-products even in heavily contaminated water and ballast treated with chlorine dioxide is environmentally acceptable at discharge. Most importantly, chlorine dioxide can be safely and economically generated in dilute solutions on board commercial vessels.

Ecochlor Inc. installed its patented treatment system on board an Atlantic Container Lines vessel in the summer of 2004. The M/V Atlantic Compass is a Swedish Flagged, RORO/Container vessel. The vessel has a dead weight tonnage (DWT) of 51,648 metric tons.

Ecochlor Inc. completed an installation on the M/V Moku Pahu, operated by Matson Navigation, in early September of 2005. The M/V Moku Pahu is a U.S. flagged, Integrated Tug/Barge (ITB) bulk carrier. The vessel has a DWT of 37,107 metric tons and a combined (tug and barge) overall length of 209 meters (685 feet).

The Ecochlor Ballast Water Treatment systems on these two vessels are each capable of treating in excess of 2,500 m^3 per hour of ballast water flow.

This paper will discuss the treatment technology, the vessels and the installation specifics. In addition, an update on performance testing and regulatory approvals will be provided.

Effectiveness and Kinetics of Ferrate as a Disinfectant for Ballast Water

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The introduction of aquatic nuisance species (ANS) and bacterial pathogens from discharge of ballast water by sea-faring vessels is an ongoing problem that threatens ecosystems and human health. New techniques and equipment for the preparation of ferrate make it a promising, cost-effective, environmentally-friendly alternative to current disinfection processes. These include mid-ocean ballast exchange, which is relatively ineffective[1], and chlorine treatment, which produces potentially harmful byproducts that have recently been limited by the EPA.[2] Ferrate is iron with a valence of +6, making it an extremely powerful oxidant. As a result it acts as a powerful disinfectant and results in organism/cell death. Therefore, the goal of this study was to investigate the action of ferrate in a marine environment, which was accomplished by growing bacteria in salt water and testing the effect of ferrate upon them, also in salt water. Four organisms have been tested so far: *Escherichia coli, Klebsiella pneumoniae, Enterococcus faecium*, and *E. faecilis*. This represents three of the major groups of organisms listed by international standards for ballast water management: heterotrophs, coliforms, and Enterococci. Organisms were grown in a 5:1 mixture of Instant Ocean:nutrient broth for 3-5 days at room temperature, with shaking, then centrifuged, and resuspended in a 5:1 mixture of Instant Ocean:distilled water. They were then treated with dosages of ferrate ranging from 0.25-5.0 mg/l. As samples were taken the ferrate was reduced with sodium thiosulfate to stop the reaction, and the organisms were quantified by heterotrophic plate count (HPC) on R2A agar, or by the IDEXX Quanti-tray system, using Enterolert or Colilert-18 for the appropriate organism. A ferrate dose of 5 mg/l resulted in at least a seven log reduction for all organisms. Smaller dosages have also been very effective, particularly if all organic material from the nutrient broth is removed by washing the cells with Instant Ocean. Ferrate appears to act very quickly, producing almost five log removals in less than five minutes at a dosage of 1.5 mg/l for *E. coli*, and somewhat lower log removals for the other organisms.

Chick-Watson analyses of the data produced an n of 2.1 for *E. coli*, 5.4 for *K. pneumoniae*, and 2.4 for Enterococci. Since n is greater than one for all organisms, this indicates that ferrate concentration is more important than contact time. Salinity (10 ppt vs. 36 ppt) did not have a clear effect on log reduction ($p > 0.05$) of *E. coli* over a range of ferrate dosages. Nor did a more alkaline pH, but a more acidic pH enhanced disinfection ($p < 0.001$) for the tested dosages of 0.75 and 1.5 mg/l.

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Ballast Water Treatment Using Crumb Rubber Filtration: Effects of Coagulation and Salinity

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Waste-tire-made crumb rubber was utilized as filter media to develop an efficient filter for ballast water treatment. Previous studies at Penn State Harrisburg indicated that crumb rubber filters could be run for a longer time or allow a higher filtration rate than conventional sand/anthracite filters because of the compressibility of crumb rubber media. In this study, Poly-aluminum-chloride (PAC) coagulant was used to enhance the removal of targeted matter (turbidity, phytoplankton and zooplankton) from ballast water by crumb rubber filtration. Various coagulant dosages were investigated. The impact of water salinity on treatment performance was also studied.

The addition of a coagulant enhanced the removal efficiencies of all targeted matter remarkably. Turbidity removal efficiency increased from about 40% without coagulation to 60% with coagulation. Phytoplankton can be removed up to 80% with coagulation while it was about 60% without coagulation. Zooplankton removal efficiency was improved from about 50% to more than 65% with coagulant addition. It also showed that varying coagulant dosage in the studied range (4.5-13.5 mg/L) did not improve the removal efficiency. But the addition of coagulant increased head loss significantly.

Salinity study indicated the removal efficiencies for turbidity and phytoplankton were higher in a high salinity water (sea water with a salinity of 22-32 part per thousand) than that in a low salinity water (fresh lake water). The average turbidity removal efficiencies were almost doubled in sea water than in lake water (27% in lake water versus 56% in sea water). Phytoplankton removal efficiency was up to 87% in sea water while the maximum was 69% in lake water. The average phytoplankton removal efficiency was about 66% in lake water and 74% in sea water. The removal efficiencies of zooplankton also got slightly improved in high salinity water. The head losses for sea water were generally higher than lake water.

The study indicated that coagulant addition and increasing water salinity could improve the removal of turbidity, zooplankton and phytoplankton from ballast water by using crumb rubber filtration. Crumb rubber filtration could be a potential primary treatment technology for ballast water and it may provide a "green engineering" solution for ballast water treatment and disposal of waste tires.

Incursion Response: Development and Testing of Tools for Use in the Marine Environment

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Responding to new incursions of fouling marine pests is hampered by both the difficult environment in which to work and the lack of effective tools for eradication and control. Application of biocidal chemicals, for instance, is often difficult in the aquatic environment. Simple removal of conspicuous pests from fouled structure or hulls, even in the early stages of invasion, is also not always effective, particularly for those species that possess a microscopic life history phase. Based upon preliminary work conducted in southern New Zealand, and also as part of the successful eradication of the invasive alga *Undaria pinnatifida* from a sunken fishing vessel, steam sterilization of substrates has potential to be a useful tool for incursion response. We report here on work conducted for Biosecurity New Zealand and Auckland Regional Council on the development and testing of steam sterilization tools on both natural and artificial substrates.

Proof of Principle Evaluation of an Innovative, Sparker-based Ballast Water Treatment Methodology

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Phoenix Science & Technology's Sparker technology was tested under contract to Transport Canada in the fall of 2005. Sparkers are sources of pressure shock pulses and light pulses generated by pulsed electric discharges between electrodes. The purpose was to establish what effect the Sparker has on various trophic levels of aquatic organisms and to evaluate the applicability of this technology for ballast water treatment.

This phase of experimental trials was intended to validate the Sparker technology's effectiveness at causing mortality in various trophic levels of aquatic organisms in warm and cold ambient water.

The Sparker technology was effective at killing larval fathead minnows with no live fish being observed after exposure to as little as 6 pulses at both warm and cold water temperatures. .

The Sparker technology was also effective at killing daphnia in experimental trials in warm and cold water. No live daphnia were observed in trials exposed to as few as 16 pulses.

As expected, the Sparker technology had minimal effect on adult zebra mussels in this study. It is assumed that the main effect on mussels came from the shock wave generated by the Sparker unit. The closer the mussels were to the unit the greater damage to the mussels shells was observed.

The Sparker technology had no effect on the algae *Selenastrum capricornutum* in this study.

Results from this study suggest that Phoenix Science & Technology's Sparker technology is effective at achieving 100% mortality in many aquatic organisms throughout the water column. This makes it a promising technology for ballast water treatment. Further study is required to determine the applicability of this technology at eliminating all organisms from ballast water tanks.

Zebra Mussel Grazing Impact on Phytoplankton Community Composition of Lake Erken, Sweden

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Biological invasion by nonindigenous species such as zebra mussel, *Dreissena polymorpha*, has a strong effect on aquatic communities and food web structure by selective feeding and consuming large amounts of phytoplankton . Neither the zebra mussel selective grazing nor the mechanisms associated with their ability to adjust feeding behaviour to compensate for poor food quality is well understood. To investigate grazing impact of the zebra mussel on Lake Erken phytoplankton community structure as well as to provide valuable insight into selective grazing by *Dreissena*, net clearance rate and pseudofaeces production of the zebra mussel were determined from April to November 2005 when subjected to the natural seston of the lake. The technique utilized was delayed fluorescence (DF) excitation spectroscopy. Six algal classes were followed: cyanobacteria (blue-green algae), chlorophytes (green algae), diatoms, cryptophyceans, dinoflagellates and chrysophyceans from one location in the lake.

Adjusted mean of clearance rates and pseudofaeces production of zebra mussels varied between algal classes and ranged from 2.7 to 16.9 mL/ mg DW mussel/h and 0.8 to 37.2 ng chlorophyll / mg DW mussel, respectively. Higher clearance rate and lower pseudofaeces production on high-quality phytoplankton including: cryptophyceans, chrysophyceans and dinoflagellates indicated selective grazing of mussels. Food quality was assumed to be attributed to concentrations of long-chain polyunsaturated fatty acid (PUFA). Diatoms responded unequally to zebra mussel grazing.

Analyses of excreted products of the zebra mussel revealed high concentration of algae larger than 50 µm and very small algae (≤ 7 µm) as well as low quality phytoplankton (chlorophytes and cyanobacteria) in pseudofaeces. With increasing initial concentration of each phytoplankton group, the amount of expelled algae in pseudofaeces tended to increase whereas clearance rate was independent of initial quantity of phytoplankton groups.

Results from the present study indicated that zebra mussel regulate their feeding behaviour to capture and ingest high quality phytoplankton with selective mechanisms to maximize acquisition of energy. In addition, zebra mussel as the primary consumer in the food web could increases the efficiency of energy transfer between trophic levels and between pelagic and benthic communities in the lakes via selective feeding on phytoplankton with high nutritional value.

Additionally, observed changes in the phytoplankton composition after zebra mussel introduction into Lake Erken are discussed. Variation in susceptibility among algal classes to mussel ingestion and strong pelagic–benthic coupling of Lake Erken implied that mussel-feeding activity could cause alteration in phytoplankton community composition of the lake and have important ecosystem consequences.

Mitigation of Dreissenid (Zebra and Quagga) Mussel Mortality on Native Unionids: A Place to Survive

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Invasion of dreissenid mussels (*Dreissena polymorpha* and *D. bugensis*) into the Great Lakes in 1986 resulted in extirpation of many regional unionid populations. Then in the mid-1990s, researchers discovered a few near-shore habitats where zebra mussel did not appear to cause unionid mortality. One such habitat in the delta-area of Lake St. Clair historically was home to 32 species of unionids including, 6 species listed as endangered in one or more of the Canadian and U.S. jurisdictions governing the area around Lake St. Clair. Many of the historical species were present in the delta as recently as 1999, even though all unionids were extirpated in nearby open waters of Lake St. Clair by 1992. In the present study, we conducted; quantitative surveys throughout the delta in 2003 and 2004, translocated unionids from high-impact to low-impact sites in 2004, and assessed the effectiveness of translocation on unionid survival and health in 2005. Between 2001 and 2003, unionid densities declined 14%, but mean infestation rates (number dreissenids/unionid) also declined from 61/unionid in 1999 to 15/unionid in 2003. Richness ranged from 3-13 species/site; density ranged from 0.02-0.13/m^2 and infestation of unionids ranged from <1 to 36/unionid/site. In general, Canadian waters of the Walpole Island First Nation Territory supported more species (13 vs. 9 species) and higher densities (20%) of unionids than sites in U.S. waters. In 2004, measures of unionid (*Lampsilis cardium* and/or *L. siliquoidea*) health revealed that glycogen concentrations were positively correlated with unionid richness and density and negatively correlated with dreissenid infestation rate. In 2005, 98% of translocated unionids were recovered live (120 of 122 individuals), recovery rates ranged from 42 to 93%, and infestation rates ranged from 1 to 3 dreissenids/unionid. Continued survival of unionids in the delta of Lake St. Clair 13 years after unionids were extirpated in the open waters of the lake is attributed to low dreissenid colonization (i.e., veliger settlement) in the delta compared to that in the open lake. We hypothesize that low infestation of unionids by dreissenids in the delta is due to prevailing currents which carry water out of the marshes of the delta preventing the in-flow of veliger-laden waters from offshore. Results indicate that habitat conditions in the delta of Lake St. Clair are favorable for continued survival of unionid clams. Therefore, delta habitats like that in Lake St. Clair should be in incorporated into management strategies to prevent further extirpation and preserve remnant populations of unionid clams in the Great Lakes.

Dreissena polymorpha in Belarus: 200 Years of Invasion, 70 Years of Research

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Dreissena polymorpha colonized Belarus in the early 18th century after canals were built in late 1700s early 1800s to connect Black Sea and Baltic Sea basins for international trade. Over last 70 years more than a hundred papers have been published on the distribution of zebra mussels, their population dynamics, reproduction, and growth, as well as their ecosystem impacts, and their endosymbionts.

The historic spread of zebra mussels in Belarus was limited to those few lakes directly connected to shipping routes. In the Soviet Belarus commercial fishing was the major vector that spread zebra mussels to isolated lakes through overland routes. After the Soviet Union dissolved, recreational activities have become much more common and are now responsible for the spread of zebra mussels in Belarus. The rate of spread of zebra mussels from the early 1800s to the mid-1950s was approximately 4 lakes every 50 years. However, since the 1960s this rate has increased to 23 lakes every 10 years due to more intense and diverse human activity in these lakes, as well as by secondary invasion from nearby invaded lakes.

Zebra mussel growth rates depend on water temperature, season of the year, trophic conditions of a waterbody, and water current. The population density and biomass of zebra mussels is different among and within waterbodies, and depends upon the type of waterbody, available substrates, the amount of local pollution and time since initial colonization.

Sixteen species and higher taxa of endosimbionts have been found within the mantle cavity and/or associated with zebra mussel tissue, including ciliates, trematodes, nematodes, chironomids, oligochaetes, mites, and leaches.

The local ecological effects of zebra mussels include changes in species composition density and biomass of native bottom invertebrates. System wide effects include an alteration of entire aquatic communities and abiotic parameters, including increases in water trancparency, macrophyte overgrowth, and abundance of bentivorous fish, and decreases in the density of phytoplankton, zooplankton, chlorophyll content, total phosphorous, and concentrations of suspended matter.

Early Life Stages of Zebra Mussels: The Importance of Long-term Datasets in Invasion Ecology

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Monitoring of *Dreissena polymorpha* larvae and juvenile settlement have often been used as a quick detection tool for this exotic species. Long-term annual monitoring of early life stages is not common however, and ideally involves sampling from the early years of a successful invasion through to the stage where maximum densities of zebra mussels occur.

Larval and juvenile *Dreissena* sampling was carried out in Lough Key, Co. Roscommon, Ireland each summer between 1998 (early invasive stage) and 2005. Researching the dynamics of early *Dreissena* life stages involved estimating the following: duration of spawning season, larval densities, larval size distributions and zebra mussel juvenile settlement rates. Adult zebra mussels were also sampled from 1998-2003. Biomass of adult *Dreissena* peaked at the start of the millennium, i.e., within five years of estimated introduction of this species.

Larval densities increased yearly from 1998 to 2003. Weekly larval size distribution analysis provided a bridge in information between larval density and settlement stages. Settlement plate data provided an indication of overall survival of larvae to the settlement stage during each sampling season. Size distribution analysis of adults from stony substrates in the years consecutive to settlement provided similar information on recruitment and survival to the 1+ stage.

This study looks at long-term datasets and shows the annual variation in early life stages during the zebra mussel spawning seasons in Lough Key. This research augments studies on adult *Dreissena* and provides valuable ecological data for increased understanding of population dynamics.

Dispersal Pathways of *Dreissena polymorpha*: Results of PCR Based AFLP-fingerprinting

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The zebra mussel, *Dreissena polymorpha* (Pallas, 1771), is an aquatic nuisance invasive species originally native to the Ponto-Caspian region where they were found in lakes and delta areas of large rivers draining into the Black and Caspian seas. The dispersal of *D. polymorpha* began at about the end of the 18th century, when shipping trade became increasingly important and inter-linking of navigable rivers through canal systems became prevalent in Europe. Over the past 200 years, zebra mussels have spread to most of the lakes, rivers and waterways in Europe by natural as well as anthropogenic dispersal mechanisms. In 1986, the zebra mussel invaded the Great Lakes in North America, most likely introduced as larvae via ballast water discharge of transoceanic ships originating from the European waters. Zebra mussel invasion in Europe and North America has caused severe detrimental impacts to native fauna, not to mention economic losses to industries by means of clogging of pipelines used for water supply.

Recently, genetic analyses have successfully been used to determine phylogeographic relationships, which may reflect invasion corridors and can help retrace source populations. The zebra mussels from populations in Ireland, Great Britain, The Netherlands, Belgium, France, Germany, Switzerland, Spain, Italy, Romania, Hungary, Poland, Ukraine, Lithuania and North America were analyzed using PCR based amplified fragment length polymorphisms (AFLP)-fingerprinting to determine the dispersal pathways of *D. polymorpha*. Our phylogenetic analysis revealed five distinct clusters. Using the fingerprinting technique, genetic variabilities have been established in 34 different *D. polymorpha* populations collected from 15 countries in Europe and North America, in order to identify the source population(s) and to trace dispersal pathways.

Eukaryotic Mantle-Cavity Symbionts of *Dreissena polymorpha* in Spain, Ireland, France, England and Poland

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Studies are scarce or lacking on symbionts of invasive zebra mussel populations established in Ireland during the past 10 years, and in Spain during the past 5 years; furthermore, reports for other European areas generally have not coordinated sampling of old and newly colonized sites for comparisons.

Between late summer 2003 and late spring 2005, we sampled several areas for comparison (listed beginning with the most recently colonized): 1) sites along the Rio Ebro in Spain colonized between 1998-2001; 2) sites along the Shannon River and numerous isolated lakes in Ireland colonized at various times between 1993 and 2004; 3) a site in France colonized in the middle 1800s; 3) a site in England colonized in the early 1800s; and 5) a site in Poland first noted in the mid 1700s. Mussels were fixed whole in the field in 75-95% ethanol, necropsied in the laboratory under a dissecting microscope, and tissue extracts were examined under a compound light microscope using brightfield and differential interference contrast optics. Voucher specimens were deposited in the Museum of Comparative Zoology of Harvard University.

Eukaryotic symbionts occurred in the mantle cavity of mussels from 15 of the 19 Ireland sites (78.9%) sampled in 2004. Prevalence ranged from 0% to 100% of mussels at any given site, but across all sites, 51.3% of the mussels examined harbored at least one mantle-cavity symbiont. At least one symbiont occurred in 100% of the mussels from the England site, 75% of those from the Spain site, and 25% of those from the France site, but in none from the Poland site.

The obligate host-specific ciliate protozoan, *Conchophthirus acuminatus*, infected up to 100% of the mussels at some sites, with numbers per host ranging up to a mean sampling intensity (i.e., per 1 ml of host biopsy) of 13.66. It occurred in 12 of 19 Ireland sites (63.2%) sampled in 2004, including all six (100%) of the sites on the Shannon and Erne Navigations, but only six (46.2%) of the 13 isolated lakes. Prevalence ranged from 25% to 100% (70.8% overall) at navigation sites, and from 0% to 100% (30.8% overall) in isolated lakes (overall Ireland prevalence 43.4%).

Metazoan symbionts consisted of various nematode, oligochaete, acarine, and chironomid species. Nematodes, the most common metazoan symbionts, occurred in seven of 19 Ireland sites (36.8%) sampled in 2004. Four of these were isolated lakes (30.8% of isolated sites), but three were in main navigations (50% of navigation sites; two in Erne and one in Shannon). Prevalence was 50% at both of the Erne Navigation sites, and 25% at all other sites (overall Ireland prevalence 11.8%). Nematodes occurred in 100% of the mussels collected at the England site, and 50% of those from the Spain site. None occurred in the France and Poland sites.

Taken together with previous studies in the St. Lawrence River, these results corroborate our previous conclusion that the zebra mussel invasion of North America was exclusively by planktonic veliger larvae, compared with common invasion by adult mussels throughout Europe.

Predators, Endosymbionts and Benthic Competitors of Zebra Mussels: Interactions and Impacts

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The relationships between predators and their prey, between endosymbionts and their hosts, and between benthic competitors have the potential to be dynamic, two-way interactions. This paper analyzes the types of interactions and the impacts that zebra mussels (*Dreissena* spp.) share with these groups. Combining studies from Europe and North America, 103, 33, and 11 species have been field-documented, respectively, as predators, endosymbionts, and competitors. As zebra mussels expanded their range over the last two centuries into Western Europe and more recently into North America, molluscivorous predators, primarily birds and fish, have continued to take advantage of them as a food source. There is also clear evidence that their obligate endosymbionts, primarily ciliates and trematodes, accompanied them during their invasion throughout Western Europe. In contrast, evidence of the transport of their endosymbionts to North America is lacking, as none of the host-specific, obligate species known from European zebra mussels have yet to be recorded from North American populations. The concept, often popularized, that natural enemies are a major controlling influence on zebra mussel populations is unsubstantiated by scientific evidence to date. There are reports of significant impacts by natural enemies, but these reductions are typically only temporal and in isolated, local sampling areas within a waterbody. Primarily because of the enormous reproductive potential of *Dreissena* and the relatively low densities of natural enemies, they likely play only a limited role in the long-term (i.e., multi-year) suppression of zebra mussel population in most waterbodies.

Accumulation of Human Waterborne Parasites by Zebra Mussels (*Dreissena polymorpha*) and Asian Freshwater Clams (*Corbicula fluminea*)

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Zebra mussels (*Dreissena polymorpha*) and Asian freshwater clams (*Corbicula fluminea*) are nonindigenous invasive bivalves present in North American fresh waters that are frequently contaminated with human enteric parasites, *Cryptosporidium parvum* and *Giardia lamblia*. Six-week laboratory exposure of *D. polymorpha* and *Corbicula fluminea* to both parasites seeded daily at concentrations reported from surface waters demonstrated efficient removal of *Cryptosporidium 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. Oocysts outnumbered cysts in the tissue of both bivalves, and more parasites were identified in *D. polymorpha* than in *Corbicula fluminea*; overall 35.0% and 16.3% of the parasites seeded, respectively. Because *C. fluminea* and *D. polymorph*a can accumulate human waterborne parasites in proportion to ambient concentrations, these species of bivalves can be effective bioindicators of contamination of freshwater habitats with *cryptosporidium* and *giardia*.

Oklahoma Zebra Mussel (*Dreissena polymorpha*) Distribution with a Focus on Densities, Settling, and Growth in Lake Oologah, Oklahoma

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Zebra mussels (*Dreissena polymorpha*) were discovered in Lake Oologah, Oklahoma in June 2003. Since that time, a monitoring study has been underway to characterize veliger densities, settling and growth rates, and adult densities at four locations around the southeastern portion of the lake. Baseline water chemistry, zooplankton net tows, veliger settling rates, and adult mussel densities have been recorded on a weekly or bi-weekly schedule. Spawning occurs when water temperatures are above 12ºC, which results in veligers present in the lake from mid-April through November. Maximum planktonic veliger abundances reached 30 per liter in September 2003, 174 per liter in July 2004, and 380 per liter in May of 2005. Increases in settled veligers on glass slides are associated with increases in planktonic veligers. Early to mid-summer growth rates for juvenile mussels averaged 2 mm per month in 2004 and 2005. Adult mussel densities on suspended concrete panels reached 30,000 per square meter in November 2003 and 155,000 per square meter in 2004.

Estimating the Economic Impacts of Aquatic Invasive Species

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In July 2005, the U.S. Environmental Protection Agency's Office of Water and National Center for Environmental Economics co-hosted a workshop of aquatic invasion ecologists, natural resource economists, and Federal aquatic invasive species program managers to gather individual experts' opinions on potential conceptual frameworks and bio-economic tools for developing national and regional estimates of the market and non-market economic impacts of aquatic invasive species (AIS). Although no consensus was reached, the weight of the individual experts' opinions indicated that:

- estimations of the economic impacts of individual AIS or AIS pathways are most feasible;
- sufficient credible data exists to develop regional estimates of AIS economic impacts; national estimates of AIS economic impacts could be derived from the credible aggregation of those regional estimates;
- investigators should be opportunistic and pragmatic as they design approaches to estimating AIS economic impacts, since it is impractical to assume that data for a comprehensive estimate will become available even in the long term;
- existing ecological information and tools of economic valuation, including willingness-to-pay valuation methods, could be used to develop timely, credible estimates of AIS economic impacts; and
- estimates of AIS economic impacts would help policymakers and managers decide among alternative management approaches on the most efficient and cost-effective options.

This presentation will summarize these and other results of this workshop and discuss upcoming interagency initiatives to fund research to estimate regional AIS economic impacts.

Estimating the Economic Impact of Zebra Mussels Within Their North American Range, 1989 to 2004

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Since 1989 zebra mussels have affected surface-water dependent electric power generation and drinking water treatment facilities throughout the eastern half of North America. Estimates of the economic impact were made by New York Sea Grant and the National Aquatic Nuisance Species Clearinghouse in 1995 but no comprehensive study has been conducted since then to estimate the overall costs and how they may have changed over time. A mail questionnaire was distributed in the fall of 2004 to all electric power generation and drinking water treatment facilities that could be identified in the U.S. states and Canadian provinces where zebra mussels were thought to exist. Facilities indicating they were not surface water dependent were dropped from the survey. The response rate based on surface water users was 31% for electric power generation facilities and 41% for drinking water treatment facilities. Telephone interviews were conducted with 50 electric generation and 50 drinking water treatment non-responding companies to assess differences between respondents and non-respondents. The number experiencing an economic impact due to zebra mussels was the only variable for which a difference could be detected between respondents and non-respondents. Almost half (46%) of the respondents spent money or experienced an economic loss compared to one-third (31%) of non-respondents. Estimates of economic impact were weighted to account for this difference. More than one-third (37%) of respondents reported finding zebra mussels in the facility. Most discoveries were made between 1989 and 1998. Almost half (45%) of all facilities have initiated preventative measures to prevent zebra mussels from impacting facility operations. Almost all facilities (91%) with zebra mussels have used control or mitigation alternatives to remove or control zebra mussels. Facilities indicated an economic impact of on average half a million dollars between 1989 and the time they completed the questionnaire in 2004 (Oct. or Nov.). Adjusting for non-response bias in the percent of facilities reporting an economic impact, we estimated that 36% of facilities (468) experienced an economic impact. We estimated that $268 million of zebra mussel related impacts were incurred throughout the study area through late 2004. More expenses were incurred during the early years of zebra mussel infestation than in recent years, with the most money being spent on prevention efforts. Lost production and revenues also contributed significantly to the overall estimate of impacts.

Introduction of the Carp *Cyprinus Carpio* into Lake Naivasha, Kenya: Economic Saviour or Ecological Disaster?

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The commercial fishery of Lake Naivasha, a 150km^2 freshwater lake in Kenya's Rift Valley, has seriously declined in recent years, with causal factors relating to climatic variables and increased pressure in the lake catchment from human population expansions and associated stresses, including abstraction, intensive agriculture and over-fishing. The fishery has been based entirely on nonindigenous species introduced since 1928 that established sufficiently to enable exploitation. These include the large mouth bass *Micropterus salmoides*, and the tilapia species *Oreochromis leucosticus* and *Tilapia zillii*. Although *O. leucosticus* was the dominant species in the commercial catches up to 2000, comprising up to 94% of all catches, their catches have since crashed, corresponding with the overall decline in the fishery.

Notwithstanding the large decline in catches of *O. leucosticus*, following the recent introduction of a highly invasive fish species, there is hope for the restoration of both the catches and economic value of the commercial fishery. The carp *Cyprinus carpio* – a highly invasive cyprinid species across the globe – was accidentally introduced into Lake Naivasha in 1998 and has since successfully established a sustainable population that has been exploited heavily in the commercial fishery since 2003. In 2004, they comprised up to 92% of the declared monthly catches by weight, and 75% by value. This was despite the market price of *O. leucosticus* being in excess of *C. carpio* – mean 85 Kshs/kg (Keynan Shillings ~ USD $1.10) compared to 45 Kshs/kg (0.60 US$). Furthermore, their life history traits – fast growth, early maturity, high fecundity, multiple spawning – mean the population should be resilient to further heavy exploitation and so will continue to provide a sustainable commercial fishery.

Notwithstanding the initiation of fishery recovery in Lake Naivasha prompted by the introduction and establishment of the invasive *C. carpio*, their introduction is likely to prove highly damaging for the ecology of the lake. This is because their feeding behaviour involves aggressive foraging in the benthos that, for example, increases water turbidity and uproots macrophytes. Therefore, whilst their introduction may have provided a future for the Lake Naivasha commercial fishery, the ecological cost may be considerable. The implication of this is discussed in the context of fishery management, the ecology of the lake and the socio-economic prospects of the region.

Household Welfare Impacts of the Water Hyacinth (*Eichhornia crassipes*) in the Kenyan Side of Lake Victoria

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The aquatic plant water hyacinth (*Eichhornia crassipes*) was first recorded in Lake Victoria at the beginning of the 1990s. The biology, ecology and impacts of water hyacinth are well studied, but its sound and cost-effective management remains an enormous challenge. Since its emergence on Lake Victoria, methods of its management have ranged from biological to physical while at the same time; studies on the use of organic herbicides have been attempted. Biological control of water hyacinth using *Neochetina* weevils has been touted as a success. A study using hypothetical markets for hyacinth control was made and results are presented. Results are then used to come up with a scheme ranking these control methods to come up with a cost effective scheme for different methods. Discussion of a possible `no control' option suggests that the economic and environmental costs of no control may be far greater than any control.

Assessing Risk Associated with Exotic Species: An Aquaculture Perspective

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Agriculture in the United States is highly dependent upon the use of nonindigenous species. Similarly, the aquaculture industry makes use of numerous nonindigenous aquatic species that comprise a diverse array of products including food, ornamentals and biocontrol. Like other industries, aquaculture can be adversely affected by introduced nonindigenous aquatic species, and has also been the source of aquatic species introductions in the past. Negative impacts associated with nonindigenous aquatic species in future may be reduced by identifying species that pose a risk, and then ensuring that appropriate measures are taken to mitigate that risk.

A generic process for risk analysis of nonindigenous aquatic species was developed by the Aquatic Nuisance Species Task Force. This process involves both a risk assessment component and also a risk management component. The risk assessment procedure determines the risk associated with establishment of a nonindigenous aquatic species, and also the risk associated with damage inflicted by that species if it becomes established. The risk management component identifies the means to mitigate risks associated with establishment and damage, determined by the risk assessment. Both components are essential to risk analysis of nonindigenous aquatic species. A third essential component is stakeholder involvement. The people who are involved with the nonindigenous aquatic species in trade must be included in the risk analysis process to ensure stakeholder support in the outcome.

The impact of invasive species issues on aquaculture will increase as federal and state agencies respond to new legislation regulating the importation and regulation of nonindigenous aquatic species. Unfortunately, there is no standard protocol for risk analysis that is uniformly applied by federal and state agencies. Essential components of risk analysis (such as risk management or stakeholder involvement) can be overlooked or left out completely, with negative consequences for both stakeholders and risk managers. This presentation will focus on the ways in which the aquaculture industry can be included as active participants in a science-based risk assessment process.

Exotic Aquatic Species Introductions in the Philippines for Aquaculture – A Threat to Biodiversity or a Boon to the Economy?

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An exotic organism is a plant or animal that has been transplanted by humans; they are usually perceived from a negative point of view. The issue of exotic species transfer is of international concern pertaining to the high risk of diseases introduction, disruptive effects on aquatic communities and environment as well as the degradation of the genetic quality of host stocks. There is tendency for an introduced aquatic organism to adopt a niche that differs completely from that occupied in its native range.

Most progressive agriculture worldwide is based on exotic animal organisms, subjected to modern husbandry contributing to animal protein production. Aquatic organisms introductions in many countries have played a major role in aquaculture, one of the world's fastest growing food production sectors. The significance of aquaculture lies on the fact that fish plays a major role in the diet of many Asian countries; over one-half of animal protein intake comes from fish. In the Philippines, per capita consumption of fish in 1978, 1982, 1989 and 1993 were 37.2, 41.2, 40.5 and 36.1 kg year-1, higher than the consumption of pork, beef and poultry meat and their products.

Philippine experiences on aquatic exotic species are not always a boom to agriculture but there are also bane stories. This paper reports some cases of some aquatic invasive species such as tilapias, carps, golden apple snail *Pomacea cananiculata*, janitor fish *Hypostomus plecostomus*, red bellied pacu *Piaractus brachypomum* and Australian red claw *Cherax quadricarinatus* and Lousiana crayfish *Procambarus clarkii*, their impacts on the ecosystem and biodiversity, agriculture and fisheries and national economy.

Tilapias from its native range of Africa and the Middle East are now of major importance in the aquaculture sector of the Philippines providing an important substitute for the declining production from capture fisheries. However, there are reports on the negative environmental impact of tilapia introduction in the country. The introduction of *O. mossambicus* resulted in the competition for food with *Chanos chanos* in brackishwater aquaculture. The indiscriminate introduction of tilapia caused the reduction of the population of native fishes *Mistichthys luzonensis* and *Sardinella tawilis*. The introduction of new strains of *O. niloticus* from Africa and the Middle East might have brought new species of parasites in the country. The case of the golden apple snail *Pomacea cananiculata* Lamarck, a South American freshwater and herbivorous gastropod introduced to the country in 1983, introduced as a source of protein for the diet of Filipinos, has remarkably invaded the rice fields and caused a massive infestation and destruction of newly planted rice plants which caused a major decline in rice production in 1983-1986. This aquatic species is now a major pest in rice farming and consequently gave rice to the use of another chemical pesticide in rice farming.

Biological Invasion Control and Ecosystem Disturbance: A Bio-economic Analysis of the Bay of Brest Scallop Fishery, France

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This paper deals with the economic impact of an aquatic invasive alien species on a coastal shellfish fishery in a disturbed ecosystem. A slipper-limpet (*Crepidula fornicata*) was accidentally imported some decades ago in the bay of Brest, France. This exotic species is spreading and acting as a space competitor for the common scallop (*Pecten maximus*) harvested by fishers. The invasion is a threat to the sustainability of the shellfish fishery and a control program is regarding. The problem is complicated by the occurrence of occasional harmful algal blooms (*Karenia mikimotoi*) related to the slipper-limpet spread and affecting the scallop reproduction.

The paper presents a bio-economic model analysing interactions between the native species, the invasive one and toxic algal blooms, and consequences on the fishery. The model combines the dynamics of the two competing stocks, the dynamics of the blooms connected to the invasive stock level and the fishery harvesting function. The analysis discusses further research needs to improve the invasive process, the relationship between the blooms and the invasive biomass, and the impacts of harmful algal blooms on the biology and harvesting of scallops.

The Prevalance of Taura Syndrome Virus, White Spot Syndrome Virus and Yellow Head Virus in Wild Shrimp Species in Thailand

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One of the ecological concerns of introducing an alien species for aquaculture is the introduction of alien pathogens and possible infection of native species. Since early 1990s, Pacific white shrimp (*Penaeus vannamei*) has been imported to many Asian countries for aquaculture. In Thailand, *P. vannamei* was first introduced in 1998. Despite Thailand's regulations on importing only pathogen-free broodstocks, the marine shrimp industry experienced outbreaks of Taura Syndrome Virus (TSV), specific pathogen to *P. vannamei* in 2003. Our study examined the presence of TSV and native viral pathogens, namely White Spot Syndrome Virus (WSSV) and Yellow Head Virus (YHV) in the wild populations of native Penaeid shrimp. During December, 2004 to February, 2005, we screened the presence of the viruses in mature wild-caught *P. monodon* (10 males and 20 females), and 6 males of *P. merguiensis* from the Gulf of Thailand and some Penaeid shrimp native to the Bangpakong estury, Thailand. We performed nested RT-PCR (IQ2000™ TSV Detection and Prevention System from Farming IntelliGene Tech. Corp., Taiwan) and by immuno dot-blot technique via monoclonal antibody raised specifically to the YHV and WSSV (a gift from Sithigorngul et al., 2000 for YHV and Chalvisuthangkura et al., 2004 for WSSV). Preliminary results indicated that a) both sex of *P. monodon* had high prevalence for TSV (at 100% in male and 25% in female) and WSSV (at 25% in male and 90% in female) but not YHV; b) male *P. merguiensis* tested positive only TSV (prevalence at 50%); and c) The viruses were detected in individuals from various shrimp species (0-40% for TSV; 0-85% for WSSV; 0-71.4% for YHV). The study indicated TSV has infected Thailand's wild shrimp and the presence of three viruses found in broodstock of *P. monodon* and *P. merguiensis* could, in turn, affect marine shrimp aquaculture industry.

Can the Spread of Invasive Species by Hull Fouling Be Controlled?

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Several methods have been proposed to control the spread on nonindigenous species in ballast water. Hull fouling is a more important vector for many species, but antifouling the under-water surface is the only current method to address this threat. Toxic coatings, particularly antifouling paints incorporating tributyltin as the active agent, can be very effective but they pose environmental problems and are being phased-out. Non-toxic coatings, such as ablating hydrophilic polymer films, silicones and low free surface energy polymer films, are less effective. The antifouling properties of hydrophilic polymer films (e.g., sulphonic acid based copolymers) stem from their self-polishing/self-smoothing characteristics, which generally need a flow approaching 10 m s^{-1} to be effective; silicones are only effective at flows greater than 10 m s^{-1}. Thus, they are ineffective in low-flow areas such as sea-chests, bow-thruster tubes, stabiliser pockets and the cavities around the stern tubes and propellers. Low free surface energy films (analogous to Teflon coatings) are less susceptible to flow rate, but are not sufficiently robust for commercial shipping applications.

An alternative approach is to treat any established hull fouling when the vessel is in port, thus limiting the spread of transported nonindigenous species. Control can be achieved by surrounding the hull with a thin layer of treatment solution, contained within an environmental capsule. This approach has the advantage of containing any organisms that are not killed. A similar technique, the "habitat tent", is currently used to carry out localised underwater repairs on ships alongside; this could readily be adapted if only high-risk areas of the hull were to be treated. Alternatively, a close-fitting hanging curtain could be suspended around the vessel to contain a sufficient concentration of the treatment solution. Suitable treatments, which are used in power stations, include heat, osmotic shock using low-grade fresh water, chemical de-oxygenation, oxidising biocides or a combination of these. Treatment could be effected within the normal turn-around time.

This paper aims to provoke discussion on methods to limit the spread of nonindigenous species transported as hull fouling. It proposes some potential encapsulation treatments, and explores their engineering feasibility, efficacy and cost implications.

Biofouling as a Vector for the Introduction of Nonindigenous Marine Species to New Zealand: Evaluation of Risks from Recreational Yachts

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Fouling of vessel hulls is an important pathway for the global transport of marine nonindigenous species (NIS). Introductions of marine NIS via hull fouling are best prevented through the development of predictive tools to identify high-risk vessels before or upon arrival to a country or new location. To evaluate the risks posed by biofouling on vessels entering New Zealand's coastal waters, the country's principal biosecurity agency, Biosecurity New Zealand, has implemented a sampling programme across a wide range of vessel types that includes recreational yachts, fishing vessels, slow-moving barges, oil platforms, passenger liners, and merchant vessels. A standard sampling methodology is being applied across all vessel types to determine the identity and relative abundance of fouling assemblages and NIS and to develop useful predictors of risk associated with the vessels' travel and maintenance history. This methodology incorporates visual estimations of biofouling abundance using an ordinal rank scale, quantitative sampling of submerged hull surfaces, and opportunistic searches in micro-habitats across the hull (e.g., rudder and propeller shafts, bow thrusters, etc.). The National Institute of Water and Atmospheric Research (NIWA) and the Cawthron Institute were contracted to sample up to 168 recreational yachts arriving in New Zealand between July 2005 and February 2007 using the specified protocols. Between 500 and 800 private recreational yachts enter New Zealand coastal waters each year from overseas. Most of these arrive in northern New Zealand, after travelling through the tropical Pacific, and spend time sailing among some of New Zealand's most highly valued marine environments. To date, approximately 30% of the targeted yachts have been sampled. In this paper, we describe the target population, the sampling design and provide preliminary analyses and results of the occurrence and distribution of biofouling on recreational yachts.

En route Survivorship of Biofouling Organisms on Various Vessel Types

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Biofouling is one of the single most important vectors for the dispersal of nonindigenous marine species (NIMS). However, it is still not known which vessels, vessel routes, and levels of biofouling (e.g., species richness, diversity, abundance, percentage cover, biomass, etc.) constitute the greatest biosecurity risk for translocating biofouling organisms to new locations.

The greatest biosecurity risk could lie with slow-moving vessels such as barges, oil exploration rigs, floating dry-docks, decommissioned, specialised, and recreational vessels. Such vessel types typically spend prolonged periods of time stationary, thus they are renowned for accumulating extensive biofouling over the entire hull, including NIMS that are capable of surviving slow voyages to new locations. Alternatively, the biosecurity risk of more active and faster moving vessels such as merchant vessels, tankers, and cruise ships may also be relatively high considering high levels of biofouling, including NIMS, have been observed within anomaly areas of the hull (e.g., dry docking support strips, bow thruster tunnels, around bilge keels, rope guards, sea chests, and rudder posts) as a result of variation in hydrodynamic flows and in the effectiveness of the anti-fouling paint.

The authors have undertaken a study to identify, for a range of vessel types, key factors (e.g. hull location; voyage speed; and voyage duration) which determine the *en route* survivorship of biofouling organisms. This firstly involved the development of a novel method (i.e., MAGPLATEs) for attaching per-fouled settlement plates to the hull of different vessel types. MAGPLATEs were used to attach pre-fouled settlement plates to nine different vessels visiting or operating in Picton, New Zealand (e.g., recreational vessels, towed and motorised barges, and RO/RO ferries) representing three arbitrary speed categories: slow (3-6 knots); medium (8-10 knots), and fast (14.5-22 knots).

Prior to vessel departure, divers attached three replicate MAGPLATEs at three different hull locations: 1) bow region (exposed area); 2) within a dry docking support strip in the middle of vessels (areas where anti-fouling coatings are old/ineffective); and 3) the stern region (protected area). A further three replicate MAGPLATEs were attached to a metal plate underneath a local wharf for control purposes.

Photographs were taken of all 12 MAGPLATEs, including a further three undisturbed control settlement plates, immediately after each vessel's return. All MAGPLATEs were then removed and reattached underneath the same wharf where the settlement plates accumulated the biofouling. All plates were photographed seven days later to determine the post voyage chronic survivorship of biofouling organisms after the trials and all plates removed and preserved to assist with the positive identification of biofouling organisms. A further set of settlement plates were redeployed and another set of replicate trials undertaken on the same nine vessels and voyage routes. The results from these trials will be revealed in the presentation.

Ships' Sea Chests: An Overlooked Mechanism for Species Transfers

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Ballast water and hull fouling have been considered the major human-mediated dispersal mechanisms of marine organisms. However, recent studies suggest ships' sea chests are another important mechanism that has largely been overlooked. In this study we describe the occurrence of marine organisms inside the sea chests of vessels visiting or operating in New Zealand.

Since 2000, Cawthron has sampled 53 sea chests from 42 vessels (135 to 13 621 gross weight tonnes) at maintenance facilities around New Zealand. Vessel types included fishing boats, research vessels, bulk carriers, roll-on/roll-off ferries, container vessels, dredges, frigates, cruise ships, tankers and tug boats. Twenty-three of the vessels were of domestic origin while the remaining 19 were international. All specimens above 500 µm (dead or alive) within sea chests were identified to the lowest practical taxonomic level.

A total of 151 different taxa have been identified representing one plant species and 12 animal phyla, namely Porifera (4), Cnidaria (13), Platyhelminthes (1), Nemertea (2), Nematoda (1), Mollusca (30), Bryozoa (11), Annelida (19), Sipuncula (2), Crustacea (43), Echindermata (3) and Chordata (21). Of particular interest were the presence of 85 mobile adult taxa in 45 sea chests (e.g., 10 gastropod species, 19 crabs, 4 fish, a sea urchin, a sea cucumber, and a starfish). Sixty one of the taxa were indigenous to New Zealand, 20 introduced (nonindigenous species now established), 15 nonindigenous (not yet established) and 55 were of unknown origin. Most nonindigenous (1 species of isopod, 3 species of amphipods, 6 species of molluscs and 5 species of decapods) were present on vessels operating between the South Pacific and New Zealand.

A wide variety of organisms are capable of surviving inside sea chests, highlighting the potential for sea chests to introduce nonindigenous and disperse native and introduced organisms around New Zealand. The occurrence of adult mobile stages is particularly significant and indicates that sea chests may be of greater importance than ballast water or hull fouling for dispersing certain marine species. These findings illustrate the importance of managing the ship as a whole rather than different mechanisms (i.e., ballast water, hull fouling, sea chests, etc.) in isolation. Cawthron is currently determining the *en route* survivorship of marine organisms inside sea chests and researching cost-effective treatment methods on New Zealand coastal vessels operated by the Pacifica Shipping Company Limited.

Patterns and Invasion Risk of Hull Fouling on the U.S. Pacific Coast

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On the U.S. Pacific coast, ballast water research and federal and state legislation have made significant strides in potentially reducing and preventing species introductions. Little is known about the role of the other shipping sub-vector, hull fouling, in invasive species dispersal. Basic information on hull fouling, such that knowledge of the extent and composition of biofouling on today's commercial fleet, is limited. Data on how biofouling varies according to vessel type, voyage routes, vessel speeds, voyage durations, hull husbandry regimes, and recipient ports would facilitate policy development and management of invasive species. As a first step in assessing these factors we examined shipping patterns and flux of wetted surface area (WSA) between ports over a three-year period to provide an estimate of the magnitude and variability of potential colonizable surface area arriving to West Coast port systems. We also examined the density component of this vector by surveying the underwater surfaces of nine containerships using divers in the Port of Oakland, CA and ten other vessels on dry-dock in Portland, OR.

We found that WSA and vessel type varied between port systems. For example, around 13.5 million m^2 of WSA arrived to the Lower Columbia River port system per year. Bulk carriers provided over half of the WSA. Over the same time period, containerships accounted for most of the 53.3 million m^2/yr and 27.3 million m^2/yr of WSA that arrived to LA/Long Beach and San Francisco Bay ports, respectively. The dive-based hull surveys revealed that containerships may be less prone to hull fouling, perhaps because of their faster voyage speeds and shorter port durations compared to other vessel types. The dry dock surveys provided qualitative evidence that vessels traversing different salinity regimes (high to low salinity) on a regular basis have reduced biofouling cover on their hulls.

While our data are based on a limited number of ships at this point, it suggests that ship type may be a good predictor of hull fouling because factors that are likely to influence the cover and composition of the hull fouling community may vary with ship type, e.g., average port duration and vessel speed. Additional sampling of various ship types may help to ascertain the relative importance of numerous factors in biofouling transfers and help inform states and port authorities of the threat of invasion posed by this vector.

Mobile vs. Sessile Organisms in Ship Hull Fouling; Results from a German Shipping Study

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The fouling community on ship hulls is not only comprised of sessile organisms, but also of mobile taxa. Mobile organisms may be transported for weeks or months amongst the fouling assemblage, for example in empty shells of barnacles, or in sheltered densely fouled areas of the hull. While most species of fouling organisms were sessile, 21% (23 species) of all species found on the ship hulls during this German shipping study, carried out 1992-1996, were mobile. Mobile organisms from the fouling community consisted predominantly of Amphipoda, Isopoda, Decapoda and other crustaceans. The Asian decapod crab *Hemigrapsus penicillatus* was found in empty barnacle shells in the hull fouling. This decapod was first recorded from French Atlantic waters in 1994, probably introduced in 1993. In the late summer of 1993, the crab was sampled from a ship's hull during the study. It is assumed that the crab was transported to Europe on the hull of the vessel investigated. Seaweeds and higher plants may also be entangled among other organisms. A new species was also found on the ships hull and it was difficult to convince editors of a scientific journal to publish this finding as the native range of the species can only be assumed. Further, fouling organisms are also transported on surfaces inside vessels, e.g. in-tank fouling and fouling in the ships cooling circuit. Results of this study will be outlined in detail with an emphasis of mobile taxa sampled from the ship hulls.

The Development of Management Recommendations for Merchant Vessel Fouling in California

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Passed in 2003, California's Marine Invasive Species Act renewed and expanded the state's program to prevent the introduction of nonindigenous species from merchant vessels. In addition to its existing ballast water management responsibilities, the California State Lands Commission (CSLC) was charged with the tasks of evaluating the risk of non-ballast vessel based vectors, and recommending action to reduce the discharge from NIS through this/these mechanisms. The risk evaluation and formulation of recommendations were to be conducted in consultation with a technical advisory group (TAG) that included (but was not limited to) shipping and port representatives and the U.S. Coast Guard, and final recommendations were to be provided to the state legislature by March 1, 2006.

Though vessel fouling is thought to be an important mechanism for introductions, little recent research has been conducted on the risk posed to U.S. waters. To the knowledge of this author, the only major research conducted in California during recent decades consisted of a single survey of 9 container ships in the Port of Oakland. The challenge, therefore, for the CSLC and the TAG was to formulate evaluation strategies and sound recommendations with a limited knowledge base, and within a restricted timeframe.

The TAG, composed of scientists, shipping and port representatives, non-governmental organizations, and regulatory agencies, began discussions in May 2005 with a workshop in San Francisco, CA. There, invited speakers provided background aimed towards informing subsequent discussions, and breakout discussion sessions were held to scope preliminary management considerations. Presenters included invasive species experts and fouling researchers from the U.S. mainland, Hawaii, and New Zealand, and vessel maintenance professionals from the commercial shipping industry. Subsequent meetings continued the information sharing process, and meetings late in the process shifted towards discussions on potential management frameworks for California. Wherever possible, analyses and qualitative surveys were completed using existing resources, and considered during the development of recommendations.

This presentation will provide insights into the advisory group process, results of analyses, the recommendations put forward by the California State Lands Commission to the State Legislature, and the rationale behind them.

Marine Pests Left High and Dry — New Australian Measures for Biofouling on Yachts

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Australia has developed a system to minimise the risk of marine pest translocation through biofouling on yachts' hulls and equipment. This approach has been developed as a component of the National System for the Prevention and Management of Marine Pest Incursions (National System).

Research undertaken within Australia has indicated that at least 250 introduced marine species are established in Australian ports and waters. It is believed that the majority of these may have been introduced by biofouling on vessels' hulls. Australia recognises that yachts arriving from overseas present a high risk of translocating marine pests through biofouling. Yachts tend to travel at slow speeds, undertake long voyages to numerous locations and typically remain in port environments for extended periods of time. All of these factors are conducive to biofouling organisms accumulating on yachts' hulls, rudders, mooring lines, anchor chains and internal seawater systems and potentially transfer marine pests.

The significant impact of marine pests from biofouling can be demonstrated by the black-striped mussel incursion in Darwin in 1999. It is believed that the incursion resulted from biofouling on a yacht that arrived from overseas. This incursion severely impacted the marine environment and resulted in significant expenditure for eradication. Implementing a system to manage biofouling on yachts will help minimise future incursions of marine pests.

The Australian Quarantine and Inspection Service (AQIS) has implemented voluntary biofouling requirements for yachts and has begun inspecting yachts' hulls and equipment. This inspection is conducted as part of a routine quarantine clearance at the vessel's first port of call in Australia. Quarantine officials undertake a visual inspection of the yachts' hull and equipment, check documentation of hull cleaning or anti-fouling paint application and provide advice on voluntary cleaning or treatment procedures.

The voluntary phase will be a crucial learning period whereby AQIS will trial the use of underwater cameras and collect data on yacht maintenance and levels of biofouling. This will enable evaluation and further refinement of the system prior to implementation of mandatory biofouling requirements for yachts.

Research is also currently being undertaken in Australia to investigate effective and appropriate methods for treating internal seawater systems of yachts. The results of this research will inform the development of requirements for managing biofouling risks from internal seawater systems.

Recreational Boating Patterns, a Useful Approach to Risk-rank Sub-regions Around Golden-Tasman Bay Region, New Zealand

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Most of the marine biosecurity effort in New Zealand has to date focused on pre border programmes. Port-border research and management has on the whole been limited to targeted eradication and control of specific introduced species (e.g., Undaria pinnatida). Although Biosecurity New Zealand is currently considering management of internal pathways for the spread of marine pests within New Zealand, there are currently few risk assessment methods available that can be applied at the regional level.

The aim of this project is to develop a marine biosecurity risk assessment model for the Golden-Tasman Bay region, located in the northern part of the South Island, New Zealand. The model integrates potential natural and human-mediated invasion pathways and the project is part of a multi-agency initiative to develop a marine biosecurity risk management plan for Port Nelson and Tasman Bay.

Golden and Tasman Bays are highly valued for their economic, environmental, social and cultural resources. The region encompasses important coastal and marine reserves (e.g., Abel Tasman National Park), fishing grounds and aquaculture areas. Although the history of marine invasions in this region is short compared to other areas in New Zealand, there have been some incursions in Golden and Tasman Bays (e.g. *Undaria* and the Pacific oyster), which have put the values of the region at risk. For this reason, it is essential to design and implement biosecurity programmes that prevent future new invasions and further spread of established pests within Golden Bay and Tasman Bay.

Recreational boating pathways within the region have been characterised as a part of the first stage of the model. Boating patterns were used to subdivide the study area into sub-regions and each sub-region was ranked based on the number of visiting vessels and a "connectivity value". This ranking is intended to help managers to define monitoring priorities and identify potential vector control measures.

An Epidemiological Model for Simulating the Spread of Introduced Marine Species by Vessel Movements and Comparing the Efficacy of Management Options

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The transport of sessile marine organisms on vessel hulls (hull fouling) is an important pathway for the spread of nonindigenous species (NIS) in aquatic environments. Many fouling NIS exhibit "stepping stone" invasions, whereby they establish initially within transport hubs, such as shipping ports and marinas, and are then spread to other locations by vectors leaving the infested hub. This type of invasion has many similarities to the epidemiology of human disease. We developed an epidemiological model, based on standard *Susceptible-Infected-Resistant* (SIR) models used in medical science, to simulate the transport of nonindigenous fouling species around New Zealand by yacht movements. The model assumes that a proportion of vessels within any infested hub port will be resistant to fouling by the NIS by virtue of their antifoulant paint, but that the susceptibility of each boat to "infection" increases as the paint ages. The proportion of "infected" boats that transport organisms to other locations is determined by the frequency of vessel movements between the infested port and other hub destinations. The model was parameterised using empirically derived data on the susceptibility of antifouling paints of different ages to colonisation by fouling organisms, and by a questionnaire survey that quantified the maintenance schedule and frequency of travel among New Zealand's coastal marinas of ~1000 domestic yachts and ~200 foreign yachts. The model also allows the user to vary a range of input variables to determine their influence on the rate and sequence of spread throughout the country. These include: the site of initial infestation by the NIS, its growth rate in infested locations, the probability of establishment by the NIS in uninfected environments, and the duration of the simulation. We used the model to evaluate the impact of three control options - 1) improved hull maintenance by vessel owners, 2) quarantine of infected vectors and marinas, and 3) early detection surveys in high-risk marinas coupled with eradication – on the rate and sequence of spread by a simulated invader. Our model is user-friendly and available as a software package for researchers, managers and other interested parties.

Habitattitude™ Baseline Survey Shows that Aquarists and Water Gardeners Can Be the Problem and Solution to AIS Spread

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Habitattitude™ is a national awareness campaign aimed at preventing the release of unwanted aquarium fish and plants into our oceans and waterways. Founded on principles of social marketing, branding, and environmental education, the campaign features a brand and prevention messages that promote alternatives to release of unwanted fish and aquatic plants into the environment. A baseline survey of aquarists and water gardeners conducted in two communities each in Minnesota and Pennsylvania suggest that *Habitattitud*e, its messages, and partners are well positioned to empower consumers to take preventative action by instilling a conservation mentality.

Aquarists and water gardeners represent potential risks for the release of unwanted aquarium fish and plants. About 30% of those surveyed had unwanted species during the past three years. Of that 30%, 18% resolved this dilemma by choosing to release fish, plants, crayfish, snails, or turtles – a total of 43 times – actions that could be harmful to the environment. Of the 82% who chose not to release, most didn't because they felt it is unethical (>90%), not good for the environment (83%), or they knew it was illegal (47%). These individuals mostly chose to resell (62%) or return to the point of purchase (49%) compared to other options. Overall, only 20% were aware of laws or regulations concerning release of aquarium or water garden species.

Importantly, aquarists and water gardeners see themselves and *Habitattitude* as parts of the solution. Most agreed or strongly agreed that: releases are preventable (89%), unwanted species should never be released (84%), and release is an environmental problem (80%). Congruent with these attitudes, over 90% agreed that the *Habitattitude* campaign's logo and messages were acceptable, easy to understand, attractive, positive, and clear. Implications of these results will be discussed with respect to on-going campaign implementation and a post campaign survey planned for 2006.

Social Marketing – Helping to Address the Aquatic Invasive Species Problems

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Globally, aquatic nuisance species (ANS) are increasingly viewed as an environmental challenge with significant ecological and economic impacts. Introduced into "new" habitats, these species can cause economic harm, degrade ecosystems and can negatively affect human health and lifestyles. Over the past fifteen years, the U.S. resource management community has developed and refined a comprehensive approach for dealing with this complex issue. A key component is public outreach and education. However, little has been done nationally to implement strategies that produce measurable results or legitimize outreach as a viable part of the equation in addressing this complex issue.

Under the national Aquatic Nuisance Species Task Force umbrella and through the shared leadership of the International Association of Fish and Wildlife Agencies (IAFWA), state fish and wildlife agencies and the U.S. Fish and Wildlife Service (USFWS), these issues are beginning to be addressed.

Beginning in 2002, the USFWS led the collaborative development of a national social marketing campaign known as Stop Aquatic Hitchhikers!™. Through efforts to enlist campaign partners, the USFWS enhanced its relationship with state fish and wildlife agencies and secured an IAFWA-sponsored grant. The two-fold focus of this 3-year project has been to increase state capacity to address ANS issues through development of comprehensive communications strategies in four pilot states (Arizona, New Hampshire, Missouri and South Carolina); and to assist the Regional Associations affiliated with IAFWA to develop a stronger voice and greater capabilities when addressing regional and national ANS regulation and enforcement issues.

This presentation will describe how a national campaign is being evaluated and how it has served as a catalyst for better internal coordination amongst state and federal conservation law enforcement staff, for enhancing in-state strategic communications amongst multiple agencies, for generating partnerships with stakeholders and constituent groups and for developing greater statewide public support for expanding the agency invasive species funding and authorities.

Public Awareness and Rapid Response Planning: Michigan's Experience with Heading Off Hydrilla

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Hydrilla verticillata is an invasive aquatic plant that has caused significant ecological disturbance and great economic cost in the southern United States. In early 2004, Michigan's Aquatic Nuisance Species Council became aware that a variety of the plant is able to survive in northern latitudes and has already become established in locations as far north as Maine and close as Pennsylvania. The council appointed a task force to develop plans for increasing public awareness of the species in Michigan and to prepare a rapid response plan for addressing the problem if it is found in the state. Michigan Sea Grant and the Michigan Office of the Great Lakes led a public awareness campaign in 2004, employing a fact sheet, Hydrilla Hunt postcard mailer and a strategic mix of other media. The task force drafted a rapid response plan, based on a model developed the Great Lakes Aquatic Nuisance Species Panel. This presentation will describe the methods and outcomes of the public awareness campaign and review the significant elements of the rapid response plan.

In the Classrooms and in the Parks: New Outreach Programs About Florida's Invasive Plants Crisis, for Science Teachers and State Park Workers

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Having more than 200 non-native plant species causing economic and environmental damage in Florida, our state could be said to be in eco-crisis. These silent invaders require more than $100 million in management costs in our fair state, every year (2004).

While the public is "aware" of invasive plants – every outdoors person knows of hydrilla and water hyacinths in Florida, even if they cannot actually identify them – the native and non-native public still does not appreciate the scope of our invasive plant problems, nor does the public know what it can do to help. (Florida's unrelenting recruitment of residents from "up north" poses continuing environmental education challenges.) Gardeners, hobbiests and landscape architects still choose invasive trees and flowers to plant in their yards and public places; they still purchase invasive herbs for their ponds; they do not realize the advantages of native over non-native plants; they cannot tell a non-native invading vine from a beneficial native vine.

One way to reach the public with correct information about Florida's plants, native and non-native, is through science teachers and state park workers.

The University of Florida and the Florida Department of Environmental Protection have therefore conceived an invasive plant education program to help inform the state's K-12 science teachers and the state's park biologists, rangers and managers.

For this program we have hired science curricula specialists and communication specialists to assist our several plant-knowledgeable information workers. During the course of one year, our team is:

a) creating bona fide curricula for schools and state parks; curricula will meet Florida's Sunshine State Standards (for education);
b) publishing science education materials for educators, students and tourists; regionalized plant ID materials will be given away; numerous kiosks will be erected;
c) hosting statewide "in-service" plant information/identification workshops; different workshops for teachers and park workers; and
d) maintaining an interactive web site featuring guided paths for teachers, according to student grade levels, and for park workers, according to park visitor interest levels.

In Year One of this demonstration program, we expect to directly reach, inform and provide unique educational materials to more than 800 science teachers; 100,000 school students; several hundred park workers; and about 250,000 state park visitors. The program also will result in "invasive plant certification" for teachers and park workers, and Continuing Education Units (CEUs) will be issued.

Evaluation of the completed program will help decide whether it will continue into subsequent years.

Empowering Teachers with Knowledge and Skills on Invasive and Exotic Species: A Teacher Workshop

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Florida is in serious trouble from the invasion of nonindigenous species. Some have been known to destroy fish and wildlife habitats directly resulting in a drastic reduction of biodiversity and ecosystem sustainability. Florida has experienced extensive problems with attempting to control, manage, or eradicate introduced species. Florida Sea Grant with the University of Florida Cooperative Extension Service has developed a meaningful educational program for teachers to improve their knowledge and skills of invasive and exotic species. A variety of standard-aligned lesson plans, classroom curriculum, and outdoor field work activities are provided for teachers to implement in the classroom. Florida Sea Grant has collaborated with representatives from Extension offices, federal agencies, and non-for-profit organizations to deliver this workshop to educators. This full-day training allows participants to identify invasive and exotic species both plants and animals, tour natural restoration areas, and participate in classroom activities and meaningful discussions. To evaluate the program's effectiveness, pre- and post-tests are administered as well as a follow-up survey of resources used in the classroom. Since 2002, 4 workshops have been taught to 90 participants. Based on program evaluations, 100% of all teachers said they increased their knowledge on invasive and exotic species, and stated they intended to use the information in the classroom. Therefore, it was estimated at least 6,000 students (3rd-12th grades) were reached with this information. Post-test scores showed a 23.2 point increase in knowledge of invasive and exotic species. The knowledge gained and skills learned will provide teachers the resources and confidence they need to translate this information into the classroom. As a result, students will become more aware of the general natural and impacts of invasive and exotic species and be able to make informed decisions regarding the protection and management of Florida's environment.

The Student Conservation Association Invasive Species Project and National Park Service – A Partnership for the Future

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The Student Conservation Association mission is to build the next generation of conservation leaders and inspire lifelong stewardship of the environment and our communities by engaging young people in hands-on service to the land. The National Park Service Exotic Plant Team mission is to control harmful exotic weeds in order to promote restoration of damaged ecosystems.

This presentation will describe the partnership developed by the NPS and SCA, which strongly supports both missions as it provides a significant opportunity for young adults to engage in field work (invasive plant management) in support of an environmental objective, the improvement, preservation and protection of habitat and ecosystems.

The SCA Invasive Species Projects are typically comprised one individual trained as the team leader, and 4-6 student team members. The SCA team leader serves as supervisor of the team members as well as the liaison between the team and the EPMT liaison. The EPMT provides a list of priority actions including inventory, control, restoration, outreach and GIS and data reporting to the SCA Team Leader. These priority actions are determined by the EPMT in consultation with the parks served. Where feasible the Corps provides education in the urban/wildland interface to provide neighbors with information on how to prevent and control harmful invasives, which threaten park land. The EPMT assists with training development and implementation. The SCA provides direct training and oversight for the student corps.

Additionally, the control and inventory actions for accountability and performance are recorded via the Alien Plant Control and Management Database (APCAM).

The SCA/NPS partnership has proved to be a successful and effective mechanism to manage invasive species while building a cadre of invasive species expertise.

The National Aquatic Nuisance Species Clearinghouse

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Stakeholders interested in the introduction, spread, impacts, prevention, management and control of nonindigenous aquatic nuisance and invasive species require timely, reliable scientific information and fast, easy access to published research pertaining to such invasive organisms. Since 1990, the National Aquatic Nuisance Species Clearinghouse has a major source of scientific information on high-priority freshwater and marine aquatic invasive species.

It is the Clearnghouse's mission to:

- facilitate and coordinate aquatic nuisance, nonindigenous aquatic species, and aquatic invasive species information (ANS/NAS/AIS) sharing among researchers world¬wide;
- provide continuity to the timely dissemination of findings of ANS/NAS/AIS research projects; and,
- facilitate ANS/NAS/AIS prevention, management and control technology transfer between researchers and stakeholder audiences worldwide.

The Clearinghouse is a major link between the global aquatic invasive species research community and university, government agency, industrial, and special interest stakeholders, and plays a high-profile role as a primary nexus for identifying current, and proposed ANS/NAS/AIS research activities and linking researchers with similar interests.

The Clearinghouse currently addresses more than thirty marine and freshwater aquatic nuisance and aquatic invasive species in a continually updated library and searchable database of 7000+ documents on specific organisms, as well as the more general topics of biological macrofouling, ballast water, exotic aquatic organisms, and North American and global invasive species policies.

All Clearinghouse information is accessible to any researcher, agency, industry, utility, student, or other individual or group anywhere in the world having need of the information via electronic mail, fax, telephone, written requests, or visits to the Clearinghouse. A keyword outline and full text searchable electronic database of the Clearinghouse's Technical Library Bibliography is available on the Clearinghouse's Web site, www.aquaticivaders.org. Citations include: author(s), title, document source and date, an annotation, type of publication, document length, document language, availability, 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, and an extensive listing of annotated "hot links" to other ANS/NAS/AIS web sites.

The Clearinghouse's quarterly publication, *Aquatic Invaders*, presents North American and global papers on ANS/NAS/AIS topics such as: research, policy, impacts, new introductions, ballast water, education and outreach, and control measures as well as useful new Web sites and meeting announcements.

The Federal Aquatic Nuisance Species Task Force and its Regional Panels, the National Invasive Species Council, and numerous state, federal, and inter¬national agencies and institutions utilize the Clearinghouse as a channel for extending information on aquatic invasive, nuisance, and nonindigenous species distribution, research, and policy initiatives. The Clearinghouse is now, more than ever, an international aquatic invasive species resource for the 21st Century.

Clean Boats, Clean Waters – A Fighting Chance!

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No one likes to fight, but when it comes to protecting Wisconsin waterways from aquatic invasive plants, that's something to fight about! Since the early 1960's, Wisconsin received its share of invasive species that inserted themselves into the environment and created havoc. The names Eurasian watermilfoil, purple loosestrife, curly-leaf pondweed, carp, and rusty crayfish are some of the more common invasive species that are in the news. As folks travel throughout Wisconsin, these exotics tag along and move from one waterbody to another. With so many waterbodies and so few state resources, it only makes sense to encourage volunteers to monitor and educate boaters about invasive species. Clean Boats, Clean Waters, volunteer watercraft inspection program, began in 2003 to assist volunteers to organize and conduct a boater education program in their community. Trained adult and youth teams educate boaters on how and where invasive species are most likely to hitch a ride into waterbodies. By performing boat and trailer checks, distributing informational brochures and collecting and reporting suspect specimens; volunteers can make a difference in helping to prevent the spread of invasive species. This presentation will describe how Wisconsin organized a statewide volunteer effort to battle invasive species and review the valuable data volunteers are collecting at the boat landings.

Effects of the Louisiana Crayfish Invasion on the African Clawless Otter in the Ewaso Ng'iro River Ecosystem

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The introduction and subsequent spread of nonindigenous species into new habitats has always been shown to have far-reaching ecological effects. This is especially true within the confines of inland aquatic ecosystems. An example is the effect of the Nile perch on the cichlid species inhabiting the Lake Victoria ecosystem. This study examined the effect of the exotic Louisiana red swamp crayfish (*Procambarus clarkii* Girard) on two indigenous aquatic species in the Ewaso Ng'iro ecosystem in central Kenya, East Africa. These are the African clawless otter (*Aonyx capensis* Schinz) and the indigenous freshwater crab (*Potamonautes neumannii*), which are predators and competitors to the crayfish, respectively. This study covered both the rainy and dry seasons in order to cover the seasonal variations in the aquatic community.

Intensive sampling suggests that crayfish have supplanted indigenous crabs in much of the lower Ewaso Ng'iro River north of the equator. This was confirmed by experimental 'competition' between captive crabs and crayfish. Crabs voluntarily leave the water to forage, so their exposure does not change with river level, unlike crayfish, which are bottom feeders.

The trap sampling also revealed that crayfish are excluded from the upper Ewaso Ng'iro (Burguret River) south of the equator by the low water temperature there. Collection of otter spraints (feces) within the study area revealed seasonal variation in the territorial marking behavior of the otters. Laboratory analysis of feces also revealed that crayfish was the primary food source used by the otters in the lower Ewaso Ng'iro, and that the availability of this resource varied between seasons. This variation was due to the increased exposure of crayfish to other predators like baboons, monitor lizards, genets, and herons. The result of this species invasion is that a stable prey base for otters (crab) has been replaced by an unstable one (crayfish) that has exposed them to increased competition.

A relationship was found between the seasonal variation in otter territorial marking behaviour of the otters and the variation in availability of crayfish. This appeared to be 'crayfish-driven' because seasonal variation in otter behavior was not observed in the Burguret River where the water temperature was too low for crayfish. Density of otters in the lower Ewaso Ng'iro River has been reducing as more terrestrial and avian predators exploit crayfish, and the data predicts a local extinction of the species by October 2005. All signs of marsh mongoose (*Atilax paludinosus*) have also been absent from the study area since March 2004. These findings illustrate the serious threat posed to Kenya's aquatic and littoral ecosystems by the continuing spread of the Louisiana crayfish.

"Inconspicuous" Impacts of Nonindigenous Species in a Pacific Northwest Estuary

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Nonindigenous species (NIS) are widely touted in the scientific and popular literature as a major threat to the environment. Some of the specific threats include extirpation of endemic species with concomitant decline in species richness, as well as loss of ecosystem services and productivity. However, these are some of the more "conspicuous" impacts of NIS, and many of the "inconspicuous" impacts of NIS invasions are poorly understood. In my presentation, I will summarize the work we have done in Willapa Bay, an estuary on the northwest coast of the United States, which has been dramatically altered by the introduction of three dozen marine NIS over the past century. While most of these NIS are inconspicuous, a handful of them (two tracheophyte species: eastern smooth cordgrass (*Spartina alterniflora*) and Japanese eelgrass (*Zostera japonica*); and two bivalve species: Pacific oysters (*Crassostrea gigas*), and Manila clams (*Venerupis philippinarum*) are dominant features of the estuarine ecosystem. By dominant we mean clearly visible to the untrained eye. In order to better understand some of the "inconspicuous" impacts of these four NIS, we used a systems approach, whereby we characterized changes in primary and secondary productivity, as well as nutrient flux. We found that the two NIS tracheophytes have increased primary productivity by 50%, and the two bivalve species have increased secondary production by 250% over peak historic values. Based on stable isotope analyses, it appears as though organic matter derived from *S. alterniflora*, is a major component of total estuarine primary productivity, and it is apparently being consumed by nonindigenous but commercially important Pacific oysters. *S. alterniflora* derived organic matter is likely exported offshore and even into nearby Grays Harbor, where *S. alterniflora* is absent. Thus, the extensive invasion in Willapa Bay has impacts in estuaries that are not directly affected by *S. alterniflora*. Given that there have not been any documented extirpations of endemic species, we conclude that species richness in Willapa Bay has increased as a result of NIS introductions. While total ecosystem productivity is clearly greater than it was historically, the sources of this productivity have changed. In total, we believe that these "inconspicuous" changes to the estuarine ecosystem add up to a rather "conspicuous" alteration in food web dynamics as well as nutrient flux.

Risk Assessment of Round Goby on Lake Trout Restoration in the Great Lakes and the Need for Mitigation

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The round goby (*Neogobius melanostomus*), an aquatic invasive species (AIS) from the Caspian Sea, now occurs in all of the North American Great Lakes but with unknown impacts on restoration of lake trout (*Salvelinus namaycush*). Lake trout were decimated in the last century by the combined effects of over fishing and the aquatic invasive species sea lamprey (*Petromyzon marinus*). Restoration of lake trout stocks has been underway for over four decades but is still considered highly vulnerable in a number of lakes to the impacts of egg and fry predators because of low egg to egg predator ratios. Round goby are a highly effective predator on eggs and fry of lake trout relative to native species, so their potential effect could be great although the impacts will depend on the abundance of round gobies relative to numbers of lake trout eggs and fry. Because of round gobies dependency on zebra mussels (*Dreissena polymorpha*) as a food source, mussel abundance is seen as a strong regulator on round goby abundance and in turn the effect of round goby on lake trout restoration. Similarly physical disturbance as it affects habitat use, and temperature as it affects ability to reproduce, are also seen as regulatory factors for round goby. Using these factors we developed a model to predict lakes and zones within lakes where the greatest impacts of gobies on lake trout could occur. Based on this model, greatest impacts are likely to occur in the nearshore waters of the lower Great Lakes where mitigation may prove necessary to limit impacts. Most effective of the mitigation techniques considered may be the construction of artificial reefs in areas where the maximum temperature is below that required for reproduction by round goby and concentrating lake trout spawning on these areas.

Winners and Losers — Do Life History Traits Promote Gammarid Invasions in Europe?

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Six life history and two ecological traits of 13 native and alien gammarid species occurring in Central European waters were compared in order to identify the characters of successful invader. Among species there were 7 native gammarids: *Gammarus fossarum*, *G. pulex*, *G. lacustris*, *G. varsoviensis*, *G. balcanicus*, *G. leopoliensis* and *G. roeselii*. All the above species there are typical dwellers of lowland and submontane waters of various characters, including springs, streams, large lowland rivers and lakes. Of 6 alien gammarids, there was one North American species, *Gammarus tigrinus*, and five Ponto-Caspian newcomers: *Chaetogammarus ischnus*, *Pontogammarus robustoides*, *Obesogammarus crassus*, *Dikerogammarus haemobaphes* and *D. villosus*. Taking into account different life cycle characteristics covered by various authors, we selected 6 life history traits that could be obtained for all the above species either from the literature or from our own data: 1) Mean breeding female size, 2) Relative age of reaching maturity, 3) Brood size, 4) Partial fecundity index, 5) Length of breeding period, 6) Number of generations per year. Additionally, two other variables that might possibly affect species invasive potential, were taken into account: 7) Salinity tolerance, 8) Tolerance towards anthropogenic. Generally the alien species were characterised by a combination of big brood size, high partial fecundity, early maturation as well as by appearance of higher number of generations per year. Also, these species presented higher tolerance towards difficult environmental conditions, ie. raised salinity and anthropogenic degradation of habitats. The above features seem to facilitate the colonisation of new areas and competition with native species – a phenomenon that has been currently observed in various parts of Europe.

Invasions as Dynamic Processes Determined by Seasonal Influences: A Study on the Invasion of the Rhine by *Dikerogammarus villosus*

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The Rhine ecosystem is highly influenced by antropogenic stress from pollution, intensive shipping and increasing connectivity with other large European rivers. Canalisation of the Lower Rhine resulted in a reduction of the heterogeneity to two main ecotopes viz. the sandy streambeds and the riverbanks, consisting of groyne stones. Both ecotopes are heavily subjected to biological invasions, affecting the food web structure. The most recent mass invader is the Ponto-Caspian amphipod Dikerogammarus villosus, showing a fast population increase particularly influencing the macroinvertebrate community on the stones by predaceous omnivory, interference competition and intraguild predation.

We studied several factors that may have determined the invasional success of *D. villosus*, such as settling and colonization of new substrate, population development, interspecific interactions and its trophic relations and physiological tolerance. The dominance and predaceous activity of *D. villosus* appeared to be highly influenced by seasonal and spatial variation. In this way, invasions may be considered as dynamical interactions that may work out differently in various ecosystems due to the heterogeneity and the spatial and temporal dynamics of the ecosystem that is invaded.

Xenodiversity of the Baltic Sea: Origin, Spread and Impacts

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Centuries of human mediated intercontinental exchange of species resulted in global mixing of previously isolated marine faunas and floras. Presently, much of Baltic marine coastal biodiversity is of foreign origin. This human-mediated addition of non-native species was termed "xenodiversity" (Gr. xenos = strange) to indicate the diversity caused by nonindigenous (alien, exotic, introduced) species (Leppäkoski & Olenin 2000). The Baltic Sea xenodiversity originates predominantly from three donor areas: the Northern Atlantic (ca. 30%, predominantly the east coast of North America) and the Ponto-Caspian area (24%). The xenodiversity might be traced at different hierarchical levels: genetic (hybridization and addition of genetically modified organisms); species (addition of alien species, elimination of native species); functional/community (emergence of novel or unusual functions, changes in community structure, alterations of food webs and ecosystem functioning) and, even habitat/landscape (habitat engineering, encrusting of solid objects, and changes in bottom micro-topography). The paper summarises results of the biological invasion studies in the Baltic Sea region during the recent decade.

Baseline Port Surveys for Invasive Marine Species in the South Atlantic Bight

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The ports of the southeastern United States are currently undergoing phenomenal growth in worldwide trade. Since ballast water discharge and hull fouling are the most significant pathways for the introduction of nonindigenous aquatic species, port regions have been identified as invasion 'hot-spots'. Baseline surveys of port regions are critical if we are to assess the current status of invasions and to reduce the risk of aquatic nuisance species being transferred to and from regions, both nationally and internationally. Current knowledge of the presence and distribution of invasive species is limited for the South Atlantic Bight region (Cape Hatteras, North Carolina to West Palm Beach, Florida). In response, we initiated a comprehensive survey for molluscan, polychaete and crustacean species in the ports of Jacksonville (Florida), Savannah (Georgia), Charleston (South Carolina), and Wilmington (North Carolina).

A GIS database of native biodiversity was also developed with the results of the surveys and from an extensive literature review for the region. This will provide baseline information against which future studies can be compared to determine the ecological impacts of invasions. Project results are presented and the limitations of the present study, in addition to future monitoring efforts are discussed.

Ecosystem-level Consequences of Spartina Invasion in West Coast Estuaries

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The eastern cordgrass *Spartina alterniflora* has been introduced in several estuaries in the western North America and has become widespread in San Francisco Bay, CA and Willapa Bay, WA. We compare the impacts of *Spartina alterniflora* in Willapa Bay with those of hybrid spartina (*S. alterniflora* x *S. folisa*) in San Francisco Bay. We document changes in light transmission, water flow and sediment deposition, total organic matter, chl a, silt/clay fraction, soil temperature, and porewater sulfide and ammonium. We also compare the results of manipulative species exclosures/enclosures experiments, additions of inorganic nutrients and stable isotope tracers experiments in both sites and compare the changes in community structure and ecosystem function. In both sites, spartina invasion has generally resulted in greater above and belowground storage of C and N relative to open mudflat of native plants. In San Francisco Bay, native species diversity and abundance is greatly reduced and there is a dramatic shift in food web structure from a largely microalgal-based system dominated by surface feeders to a largely detrital-based system dominated by subsurface feeders. Though similar changes occur in Willapa Bay, the quality and quantity of change is less in some cases. We discuss why and where the impacts of spartina differ and the consequences of these changes for higher trophic levels.

Introduced Pumpkinseed Sunfish (*Lepomis gibbosus*) Ruins Moorland Pool Restoration Projects

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The Pumpkinseed sunfish (*Lepomis gibbosus*) is an introduced species in the Netherlands originating from the United States. It is a popular aquarium and garden pond fish. Because they reproduce very well , many people dump these fishes in the natural waters, where in most cases they cause no big problems.

However, restoration efforts in moorland pools create shallow sandy shores which are ideal reproduction sites for the Pumpkinseed sunfish. By lack of biotic interactions its diet is much broader than recorded in the U.S.

Unlimited reproduction, lack of predators and competition cause high population densities of the Pumpkinseed sunfish in these waters and is therefor a threat for endangered native species by strongly reducing macroinvertebrate communities and predation on amphibian larvae of red list species. Damage on these restoration projects runs easily up to 100,000 euro per pool. Till now no good solution was found for this problem.

Dominance of the Invasive Invertebrates in the Littoral Zone of Lake Balaton (Hungary)

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Lake Balaton is the largest lake in Central Europe (length: 78 km, average width: 7.6 km, surface area: 596 km^2, mean depth: 3.25 m). It is connected with the river Danube through the Sio Canal, which flows into the south-eastern part of the lake. Three main waves of invertebrate invasive species have occurred within the last 70 years. In the decade from 1930 to 1940 *Dreissena polymorpha* (Mollusca: Bivalvia) and *Chelicorophium curvispinum* (Crustacea: Amphipoda) were introduced, via the Sio Canal, and spread quickly. In the decade of the 1950s, individuals of *Dikerogammarus* species (Crustacea: Amphipoda) were accidentally introduced together with *Limnomysis benedeni* (Crustacea: Mysidacea), which was intentionally introduced as fish food. *Jaera istri* (Crustacea: Isopoda) was identified as an invasive alien in 1994 and *Cordylophora caspia* (Hydrozoa: Clavidae) in 2001.

In order to survey the recent status of invasive species in Lake Balaton, invertebrates living on submerged macrophytes were studied from 2000-2002 and those living on stones of littoral zone from 2003-2004. Observations were made seasonally at four different stations. Of these invasive species *D. polymorpha, Chelicorophium curvispinum* and *Dikerogammarus* species (*D. haemobaphes, D. villosus* and *D. bispinosus*) are dominant and their numbers depend on the substrata, the season and location of sampling. Among *Dikerogammarus* species, *D. haemobaphes* dominated on submerged macrophytes, while *D. villosus* was found mostly in the stony littoral zone. *L. benedeni* occurred mainly on submerged macrophytes, while *J. istri* and *C. caspia* mainly on stones.

A National Incursion Response to the Invasive Diatom, *Didymosphenia geminata*, in New Zealand Freshwaters

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A national incursion response to the recently introduced invasive diatom, *Didymosphenia geminata*, has been launched by Biosecurity New Zealand, the government agency managing the risks of unwanted organisms. This single-celled benthic alga, commonly called 'rock snot' because of its extremely negative aesthetic impact, attaches to stable substrate by exuding a mucopolysaccharide stalk. It has formed massive colonies in some of New Zealand's most pristine, oligotrophic rivers, sometimes smothering kilometres of riverbed under mats up to 20 cm thick. Its discovery in October 2004 in the Waiau River, Southland was the first validated record of *D. geminata* in the Southern Hemisphere. Biosecurity New Zealand funded investigations to determine 1) distribution - by conducting presence/absence surveys and river suitability models; 2) containment - by establishing controlled areas to reduce spread using biosecurity legislative powers and by developing chemical and physical methods to eradicate the alga on risk goods transported between waterways; 3) detection - by developing methods of finding low levels of the microalga before blooms become apparent; 4) impact - by assessing risks to core values (economic, environmental, social, cultural) and by quantifying effects on river physiology, invertebrates and fish; and 5) control - by testing control methods for their a) effectiveness on cell mortality and stalk disruption, b) impact to non-target organisms, c) feasibility of application to swift flowing rivers, d) duration required for adequate control and e) cost for scaling to whole rivers. Results provide the basis of response options for the long-term management of this unwanted alga.

Standardized Ballast Water Treatment Test Facility Development – General Overview of the Technical Challenges and Needs

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International law will soon require that ship ballast water be treated by approved Ballast Water Management Systems, meeting Regulation D-2 of the "International Convention for the Control and Management of Ships' Ballast Water and Sediments". Under the sponsorship of the U.S. Coast Guard (USCG), a land based facility to verify the performance claims of marine ballast water treatment systems per U.S. Environmental Protection Agency (USEPA) Environmental Technology Verification (ETV) protocols has been established at the Naval Research Laboratory in Key West, Florida (NRLKW). The ETV protocols require testing of treatment technologies at a scale compatible with current ballast equipment and capacities found on medium sized marine vessels, using challenge water that includes surrogate aquatic species to assess treatment system performance. The ETV protocol calls for both live surrogate testing as well as maintenance cycle testing to assess operating costs, maintenance requirements, and treatment capabilities over time. In addition to serving as a research laboratory to assess protocol methods and procedures, the Ballast Water Treatment Test Facility (BWTTF) at NRLKW incorporates industrial computer based control systems and data logging to implement an automated test stand suitable for standardized verification of in-line and/or in tank ballast treatment technologies at flow rates of 300 m^3/hour. This document specifically addresses the requirements, rigor and necessity of standardized testing as a cornerstone to successful implementation of ballast water discharge standards.

Validation of Methods for the Injection of Surrogate Organisms Into Ballast Piping

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Many of the ballast water treatment technology testing standards require the addition of surrogate organisms to the test or challenge water. In some cases these organisms are identified by size class and in others they are specified by biological classification, even to the species level. As many of these organisms are not likely to be globally or seasonally available at the target concentrations, test facilities will need to add these organisms to the test fluid in a continuous, controlled manner to achieve the requisite standards. This paper describes research conducted to develop and validate surrogate injection methods. These methods included a diaphragm pump, a positive displacement pump and a pressurization chamber. Subsequent to the validation effort, a second iteration was conducted to integrate the injection mechanism into a full scale ballast water system. These results provide a realistic approach that could be utilized for the validation of surrogate organism additions at test facilities internationally.

Surrogate Population Kinetics in Ballast Water Tanks Applied to the Technology Treatment Testing

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Current approval protocols for testing ballast water treatment equipment generally include provisions for both treated water hold times (comparable to ship voyages) and surrogate organisms. In applying these within a standardized or approval testing program requires some testing to evaluate how the surrogate population and/or the indigenous population responds to various voyage/hold times at the desired volumes and concentrations. These data provide useful insight to the anticipated effects or result of non-treatment and what might be anticipated from control tank discharges. Moreover, an understanding of the population kinetics may allow for a more appropriate tank hold times. The Naval Research Laboratory in Key West Florida conducted experiments in which surrogate zooplankton (*Artemia hudsonica*), phytoplankton (*Tetraselmis*) and ambient bacteria were injected into the ballast water treatment testing system both with and without active treatment. Various incubation times of 1, 3 and 5-days were used. Water samples collected both in-line and in-tank during de-ballasting were measured for surrogate densities and viability. Results indicate that significant decreases in density and viability occur after a three-day incubation period devoid of active treatment. Furthermore, results suggest that these survival times may be species specific. Such ambient survival times need to be quantified for the mesocosms so that they are not surpassed resulting in the false confirmation that a technology was successful in its treatment efficacy.

Inorganic and Organic Content Augmentation for Controlled Water Quality Testing of Ballast Water Treatment Systems

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The evaluation and approval of treatment technologies for ballast water discharge requires standardized water conditions of which particulate and dissolved content is significant element. The amount of inorganic (sediment) and organic matter (humic matter) contained in challenge waters must be controlled since ambient waters are often seasonally variant and weather driven. The ambient waters of Flemming Key, FL provide organic carbon and suspended sediment concentrations are insufficient to meet ETV marine challenge water requirements. Consequently, organic carbon and sediment must be introduced to challenge waters used for treatment verification. This report covers a broad range of topics including investigation of potential surrogate carbon and sediment sources, their effect on microbiology, and the results of treatment by chlorination.

Analytical Tools Development for the Enumeration and Viability Determination of Aquatic Organisms

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Validation of ballast tank challenge water and verification of ballast water treatment method efficacy requires analysis of large volumes of water to determine the species present, their concentrations and the viability of detected species. When these measurements are performed manually, the shear volume of sample water that needs to be analyzed both prior to testing (challenge water verification) and following an evaluation of a treatment methodology puts a significant time and labor burden on the staff supporting the Ballast Water Treatment Test Facility at the Naval Research Laboratory in Key West. Automation of these analyses are required for these measurements to be performed consistently (e.g. avoiding person to person biases) and in a timely fashion. For the past year, the Naval Research Laboratory has been working on the specification (including any application specific modifications) and evaluation of instruments to perform these measurements. In conjunction with these instruments we are currently developing both metabolic dye systems and image processing and classification algorithms for fully automating sample analyses.

The paper will describe each of the instruments that we have configured for analysis of the ballast water samples. This will be followed with descriptions of instrument modifications, sample analysis protocols, and image processing and classification algorithms. The paper will emphasize the algorithms that we have developed for classifying and counting organism type (artemia (including their life stages), tetraselmis, and bacteria) in ballast water samples, the algorithms that we have developed for zooplankton viability classification (based on organism movements),and the metabolic dye systems that we are using for phytoplankton and bacteria viability determination. The paper will also describe how the metabolic dye systems are used in conjunction with the instrumentation for automated sample analyses.

Filter Train Performance Testing – Results of 100 Operational Hours

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Considerable efforts throughout academia and industry are currently focused on technologies to reduce or eliminate the translocation of organisms in ships ballast water. In support of these technologies, a pilot-scale facility to test candidate technologies has been constructed. The intention of the pilot scale facility is to supply a means to test shipboard equipment as close to full-scale as possible with increased control of the various parameters affecting performance, which are typically unknown or uncontrolled in the ship's environment. For example, input water properties are controlled by the surface waters which the ship typically operates in, whereas the waters utilized at the test facility may be supplemented to adjust organism densities, salinity and suspended solids. In the past, year this facility has been conducting experimentation to evaluate the test facility and also ballast water treatment equipment.

A variety of filtration technologies exist on the market today, which may be viable candidates for the removal of biological organism from ships ballast water. In the present document, the results of testing at the pilot scale facility are reported. These systems included a disc, a screen and a media filtration system. Additionally, combinations of these units were evaluated. These filters were evaluated for the relative ability to reduce particulate concentrations and biological organisms of ambient water drawn from the Gulf of Mexico. Where appropriate or necessary, the test waters were supplemented with concentrations of Arizona Test Dust to alter the total suspended solids and overall turbidity. Particle counting was used on the input and output of each filtration systems to evaluate filter removability. Direct enumeration of organisms in the feed water and filtrate were utilized to evaluate effectiveness in the removal of organism. Discussion of the performance of each system and their combinations over the size ranges 10-30, 50-80 and 100-200 microns are reported.

Risk Assessment of Snakeheads (Channidae) in Canada

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There are 29 species in the snakehead (Channidae) family native to Asia, Malaysia, Indonesia and Africa. Snakeheads have interesting life histories and ecological characteristics that vary between the species. Some species have the ability to breathe air, move overland, and remain out of water for several days. Currently, four species have been found in the United States as a result of unauthorized introductions. Snakeheads are used by humans as a food source, in the aquarium trade, and as biological control organisms. The ecological impacts on the ecosystems into which they have been introduced is currently unknown, but is expected to be significant due to their predaceous nature. As snakeheads are found in the live food fish and aquarium industries in Canada, and in the wild in the northeastern United States, there is concern about the impacts that these species would have if introduced into Canadian waters. As a result, the Canadian government conducted a risk assessment to determine the ecological risk of snakeheads to Canadian freshwater ecosystems. This assessment evaluated the risk of introduction, survival, reproduction, spread and fellow travelers (e.g., parasites, diseases). These components were assessed using best available information on their biology, potential vectors of introduction, and impacts in both native and introduced ranges. The assessment was peer-reviewed and results varied considerably between snakehead species due to their wide range of temperature tolerances and use by humans. However, it was concluded that, for some snakehead species, the risk was high in Canada.

To Stock or Not to Stock: Managing the Risk of AIS Introductions by Fish Hatcheries

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Executive Order 13112 directs each federal agency to avoid carrying out actions that "it believes are likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere," qualified by other conditions. How should federal agencies evaluate such situations? An example of this dilemma occurred in the fall of 2002, when New Zealand mudsnails (NZMS), *Potamopyrgus antipodarum*, were discovered in several springs that supply the Hagerman National Fish Hatchery (NFH) in Idaho. Concerned with the hatchery's potential to spread NZMS through fish stocking operations, the U.S. Fish and Wildlife Service (Service) conducted a risk assessment. Given the life history and physical tolerances of NZMS, introduction vectors from hatcheries include contaminated gear, contaminated stocking water, and snails ingested by stocked fish prior to transfer. The Service determined that hatchery fish releases presented a likely risk of NZMS introduction if: 1) within the last 12 months, there is evidence of at least one NZMS (dead or alive) associated with water used in rearing or transport of subject fish, inside facilities that indicate availability for consumption by subject fish, or inside subject fish, and;(2) NZMS have not yet been found in the watershed of the tributary where the hatchery release is to occur. Using these criteria, the Service determined that stocking activities for several tributaries in the Snake River watershed could lead to NZMS spread. Additional variables, including other introduction pathways and habitat suitability, were evaluated relative to this assessment to develop risk management guidelines for Hagerman NFH. These guidelines provide for continued stocking in some tributaries and cessation of stocking in others. This effort revealed the need for further research on NZMS biology and control options. Moreover, it emphasized the importance of developing a coordinated risk management strategy among all agencies operating hatcheries that are currently or vulnerable to becoming contaminated by any aquatic invasive species. Related policies for reducing the transmission of fish pathogens and disease by hatcheries can serve as a model for such a strategy.

Development of an Ecosystem Model for Investigation of Ecological Impacts of Aquatic Invasive Species in Lake Michigan

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The Lake Michigan Mass Balance Project (LMMBP) was designed to increase our understanding of the fate and transport pathways of toxic contaminants in Lake Michigan. The LMMBP included an eutrophication model (LM3-Eutro) to describe carbon production resulting from phytoplankton dynamics. While the eutrophication model is capable of simulating internal carbon loads, greater trophic level resolution to evaluate ecosystem impacts of external perturbations, such as invasion of exotic species, is required. A Lake Michigan Ecosystem Model (LM-Eco) that includes a more detailed description of trophic levels and their interactions is being developed as an enhanced version of the existing LM3-Eutro model for Lake Michigan. The LM-Eco model constitutes a first step toward a comprehensive Lake Michigan ecosystem productivity model to investigate ecosystem-level responses and effects within the lower food web of the lake. The effect of the invasive species *Bythotrephes longimanus* on individual zooplankton species was investigated based upon extensive field data collected at multiple locations in Lake Michigan during the 1994-1995 LMMBP. The LM-Eco model was successfully applied to simulate the trends of *Bythotrephes longimanus* and zooplankton abundance as observed in the collected field data. Model simulation results were analyzed as a time series specific to individual field sampling locations within the lake, and also on a lake wide scale. An additional application of the LM-Eco model is for the investigation of ecological impacts resulting from the invasion of the non-native species zebra mussel (*Dreissena polymorpha*) in Lake Michigan both spatially and temporally. This abstract does not necessarily reflect EPA policy.

Predicting the Characteristics of Aquatic Invertebrate Invaders

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Our ability to identify characteristics of species most likely to become important invaders will facilitate prevention and control of non-native species that have the potential to be introduced or have been introduced. Focusing limited time and resources in an effective way will reduce the long-term effects of invaders most likely to cause the most damage. We examined 95 species of aquatic (marine, brackish, and freshwater) macroinvertebrates and assessed a range of characters that have been considered by others to be important modulators of invasion success. Determining factors and characteristics of the most successful invaders will allow targeting of limited resources at prevention of the introduction and spread of those species most likely to invade as well as cause ecological and economic damage.

When we considered all of the data together, we found several significant correlations. We found a positive correlation between the number of different types of reproductive modes (sexual reproduction, asexual reproduction, cloning, and combinations of these) and invader success. However, we found little support for most of the generalizations that have been proposed (e.g., higher fecundity, longer dispersal distances, presence of resting stages, etc.), and found many patterns contrary to those traditionally predicted. We found that invasiveness was negatively correlated with measures of fecundity and dispersal ability. These life history characters may indicate that high larval and juvenile survivorship, as is expected with larger larval size and shorter larval duration, is more important than the numbers of larvae produced for invader success.

We found a significant negative correlation with the invasiveness of a species and its tolerance to pollution. Thus, when water regulations improve water quality, those waters may become more vulnerable to aquatic invaders. These results also suggest that as water quality improves in other regions of the world that are potential sources of invaders, we should expect an increase in the spread of exotic species from those source areas.

A Quantitative Risk Framework for the Assessment of Aquatic Invasive Species

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Risk analysis is an important tool for assessing the threat from invasive species. Here we present a quantitative risk framework to be used for the assessment of aquatic invasive species (AIS). The framework consists of several components necessary for analyzing risk including arrival, survival, establishment, spread and impact. A software interface for this quantitative risk framework was developed providing the user with the ability to enter probabilities, costs of impacts, remediation and uncertainty to estimate risk within each of the framework's components. A Great Lakes basin-related case study was used to test run the quantitative framework, which will be presented to demonstrate the uses of this framework. The use of a quantitative risk framework will (i) make risk analyses more defensible, (ii) clearly identify costs and effective targeting of resources, (iii) identify knowledge gaps and future research needs, (iv) identify which components of the risk analysis are most important for the assignment of risk, and (v) increase the level of certainty.

A Molecular Ecological Approach to Determining the Distribution, Establishment and Impacts of Invasive Species in Marine Ecosystems

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Currently, there are no predictive tools to determine if a non-native species will become invasive when introduced into a new ecosystem. This is largely due to the fact that mechanisms of invasiveness are poorly understood. As a result, there is a critical need to develop rapid, cost-effective methodologies to monitor the introduction and establishment of non-native species. To this end, we have developed a suite of species-specific DNA-based diagnostic tools to determine the abundance and distribution of native and invasive marine bivalve and crustacean larvae in the Puget Sound. These diagnostic systems are based on ribosomal DNA sequence analysis of morphologically identified adults. Internal transcribed spacer (ITS) rDNA sequences were used to design oligonucleotide primers for polymerase chain reaction analysis of water samples. Beginning in May, 2005 we used 30 and 73 micron Bongo™ nets to collect monthly plankton samples throughout Puget Sound. Total DNA was extracted from concentrated plankton samples and analyzed using taxon and species-specific PCR primers to assess the ratio of bacterial, fungal, plant, bivalve and crustacean DNA, and to monitor the distribution and abundance of specific native and non-native species. Currently, we have 11 species-specific PCR primers for native bivalve species of *Protothaca, Tresus, Clinocardium, Macoma, Saxidomus, Ostrea, Modiolus* and *Mytilus*, four non-native bivalve species of *Venerupis, Nuttallia, Mya* and *Crassostrea*, six native crustacean species of Cancer and *Pandalus* and two non-native crustacean species of *Carcinus* and *Eriocheir*. In addition, we are working to develop similar molecular diagnostic systems for several microorganisms, tunicates, echinoderms, algae, and plants. Here, we present data on the distribution of bivalves and crustaceans in Puget Sound to demonstrate the utility of this strategy for monitoring any marine ecosystem.

Identification of Specific Water Bodies at Risk for Zebra Mussel Invasion Using Boater Surveys Conducted by the 100th Meridian Initiative

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Since its inception, the principal objective of the 100th Meridian Initiative has been to prevent the westward spread of zebra mussels. Members of the 100th Meridian Initiative have conducted over 11,000 boater surveys and voluntary boat inspections in North America, focusing originally on the states intersected by 100 degrees west longitude, but more recently on all western states and the Canadian province of Manitoba. Information from these surveys, compiled into a central database maintained by The University of Texas at Arlington, has been used to assess connections between individual water bodies by trailered boat traffic. A reasonable assumption can be made that non-infested water bodies linked by considerable trailered boat traffic coming from areas infested with zebra mussels are potentially at risk for future zebra-mussel invasions. Based on 100th Meridian Initiative data, a list of top ten water bodies at risk for zebra mussel invasion was produced in 2003 when all of these listed waters remained free of zebra mussels. Now, two years later, six of the ten listed water bodies have reported zebra mussel infestations or are immediately downstream of confirmed sightings. A new analysis is currently underway at The University of Texas at Arlington and will include additional data from the latest boater surveys and recently identified zebra mussel infestations. The objective is to produce a new list of water bodies identified to be at risk based on trailered boat traffic levels. The status of this analysis will be reported at the 14th International Conference on Aquatic Invasive Species.

Ecological Plasticity of Invasive Aquatic Species: A Confounding Factor for Risk Assessments

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Assessment of the risk posed by invasive aquatic species and their potential for introduction, survival, establishment, spread and impact is largely based on the native or existing range of the species and the behavior and life history of the species within that range. When species are introduced into totally new and different systems, barriers to range expansion and factors, often unknown, that influence those behaviors are likely to be removed or be changed. Invasive aquatic species may react to, or adapt to, those changes in unexpected ways, complicating risk assessments in such a way as to potentially underestimating risk. We provide examples of invasive fish species, Asian carps being one of them, which have exhibited changes in life history and behavior that would have been difficult, or impossible, to predict during a risk assessment process prior to their introduction to North America.

Monitoring Fish Invasions and their Impacts in Southern Florida

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LIn a recent paper, we noted that the abundance of non-native fishes was generally low in freshwater marshes of the Everglades at sites distant from canals, but was relatively high in some habitats bordering that ecosystem. Further, we reported a negative correlation over a 10-year period between the numbers and biomass of native fish and the same parameter for the non-native Mayan cichlid, in mangrove habitats. Since that publication, we have observed an expansion of Mayan cichlids into Everglades wetlands adjacent to the mangrove zone. At present, we can identify no statistical evidence for effects from any non-native taxa on native fish communities in freshwater wet-prairie habitats. However, in the mangrove zone on the northern fringe of Florida Bay, the native species sheepshead minnow (*Cyprinodon variegatus*) and marsh killifish (*Fundulus confluentus*) decline in abundance in periods when Mayan cichlids are common, and increase following cold weather that decreases cichlid abundance. Two other small, abundant native fishes, sailfin molly (*Poecilia latipinna*) and rainwater killifish (*Lucania parva*), appear to be unaffected by the changing abundance of Mayan cichlids. Our work indicates that Mayan cichlids have altered the community structure and dynamics of native fishes in some habitats in southern Florida, but not in others. We discuss the ability to generalize our observations to other expansions and evaluate if predictions can be made early enough to intervene once a new fish species is detected.

Nonindigenous Fish Establishment in the Central Everglades Marsh

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Anthropogenic stresses over the past half-century have considerably impacted the function of the Everglades ecosystem, causing fish populations to decline and altering their community structure. A potential threat to restoration of the Everglades fish community is the increasing number of nonindigenous fish species in the southern Florida drainage. To date, 76 nonindigenous freshwater fish species have been identified and 35 have established breeding populations. Canals bisecting and surrounding the Everglades serve as a thermal refuge and conveyance for nonindigenous fishes, and these canals potentially permit access to the Everglades marsh. Despite the possible negative effects of nonindigenous fish to ecosystem function, their presence in the Everglades marsh and potential effects on marsh community dynamics have received little attention.

In this study, an initial survey was conducted in the Central Everglades to determine whether nonindigenous fish species are established in the Water Conservation Area 3A marsh, or restricted in distribution by proximity to the L-67A canal. To determine establishment, the nonindigenous fish relative abundance was evaluated in relation to distance from the canal. Several nonindigenous fish species were captured below published minimum temperature thresholds, suggesting that the thermal constraints cited as the primary control factor of nonindigenous fish distribution and establishment must be re-evaluated to allow better prediction of future introductions.

Assessing the Potential Impact of African Jewelfish [(*Hemichromis letourneuxi)* (Cichlidae)] in Everglades Marshes: Prey Selectivity and Anti-predator Response by Naïve Prey

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Predation is often a major mechanism underlying impact by nonindigenous (NI) fishes. In this study, we examined the susceptibility of Everglades fishes to predation by a recent invader, the African jewelfish *Hemichromis letourneuxi*. Little is known about the susceptibility of native small-bodied fishes to predation by NI fishes or whether this susceptibility differs from the predation risk native fishes experience from native predators. Prey susceptibility to predation should intimately relate to the predator's foraging preferences and/or to the prey's anti-predator response. In the case of invasions, several studies show that predation by NI species is strongly affected by the degree of naiveté of the prey species. NI species may predate opportunistically on naive prey that have no common evolutionary history with the nonindigenous predator, and thus lack anti-predator responses or show behavioral responses that are ineffective against novel predation.

To examine this issue, we conducted a prey-choice experiment in outdoor mesocosms followed by behavioral assays of antipredator response in the laboratory. Mesocosms containing a standardized amount of refuge where stocked with an assemblage of prey species. The prey species included three abundant fish species in Everglades habitats, stocked in equal densities: eastern mosquitofish *Gambusia holbrooki*, sailfin molly *Poecilia latipinna*, and flagfish *Jordanella floridae*. Survivorship of these fishes was quantified in the presence a native predator, warmouth *Lepomis gulosus*, in the presence of the introduced jewelfish, and in the absence of predators. We then quantified antipredator response (i.e., activity, refuge use, and foraging) individually by the three prey species to jewelfish and warmouth in timed trials conducted in aquaria. Our results indicated notable predation differences between jewelfish and warmouth, and in the degree of antipredator response exhibited by the prey species.

Relative Impact of Nonindigenous African Jewelfish [(*Hemichromis letourneuxi)* (Cichlidae)] on Native Everglades Fishes in Subterranean Dry-season Refuges

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The abundance of nonindigenous fishes in the Rocky Glades region of Everglades National Park (ENP) has increased dramatically in the past few years. The Rocky Glades is a short-hydroperiod karst wetland with numerous solution holes that vary from shallow, isolated depressions to deep, interconnected complexes. Solution holes provide refuges for fishes during seasonal dry-downs, and may serve as important sources of marsh colonists upon re-flooding of the marsh surface. Nonindigenous *Hemichromis letourneuxi* (African jewelfish) were first collected in Everglades solution holes in 2000; subsequently their relative abundances have increased rapidly, especially in medium (41-80 cm max. depth) and deep (> 80 cm max. depth) holes. Data collected from fish-community monitoring efforts in 2003-2004 indicate native fishes (e.g., *Gambusia holbrooki, Fundulus confluentus, Jordanella floridae*) were abundant in shallow solution holes (≤ 40 cm max. depth), but were uncommon and often absent in deep solution holes where *H. letourneuxi* was common (comprised ≈ 30% of total CPUE).

In this study, we conducted a predator inclusion/exclusion cage experiment in medium to deep solution holes in ENP to discern whether the absence of small native fishes in deep solution holes is a result of poor physicochemical conditions (e.g., low dissolved oxygen, high ammonia, etc.) or predator-induced mortality by *H. letourneuxi.* We installed two 18-cm diameter cylindrical 2-mm mesh cages containing artificial vegetation in each of 15 solution holes. We then conducted four predation trials through the course of the dry season, as abiotic conditions deteriorated. For each trial, we placed 10 *G. holbrooki* (eastern mosquitofish) in one cage and 10 *G. holbrooki* + 1 *H. letourneuxi* in the second cage. Trials ran for 7 d at which time cages were removed and fish were censused. Physicochemical data (water temperature, pH, conductivity, DO, ammonia) were collected at the beginning and end of each trial. We saw significantly higher mortality of *G. holbrooki* in the presence of *H. letourneuxi* than when the predator was absent, and saw no consistent impact of deteriorating physicochemical conditions on either predator-induced mortality of *G. holbrooki* or on *H. letourneuxi* survival during trials. Additionally, we present a survival analysis of *G. holbrooki* in solution holes through the course of the dry season. Those data were collected from a third cage installed in each solution hole, stocked with 10 *G. holbrooki* (no predator present), and censused weekly until either the hole re-flooded to the marsh surface or there was 100% mortality. Our data suggests that predator-induced mortality by nonindigenous fishes may have a deleterious impact on native fishes in refuges in this system.

Disposable Pets, Unwanted Giants: Pythons in Everglades National Park

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Reports of exotic snakes in Everglades National Park include regular and increasing sightings of Burmese pythons (*Python molurus bivittatus*). Pythons in the wild today are a result of unwanted, intentionally, and perhaps accidentally, released exotic pets. The Burmese python, a native to Southeast Asia, can reach a length greater than twenty feet. This python is a long lived (15-25 years) behavioral, habitat, and dietary generalist, capable of producing large clutches of eggs (8-107). Pythons in Everglades National Park have been observed along the main park road, in Long Pine Key, at Shark Valley, along Tamiami Trail, on the eastern park boundary, along canal levees, and in the remote mangrove backcountry. The non-native python's diet in the Everglades includes raccoon, rabbit, muskrat, squirrel, opossum, cotton rat, black rat, cat (kitten), house wren, pied-billed grebe, white ibis, and limpkin. Sources of mortality include motor vehicles, mowing equipment, fire, and alligators. As *Python molurus* is known to eat birds, and also known to frequent wading bird colonies in their native range, the proximity of python sightings to the Paurotis Pond and Tamiami West wood stork rookeries is troubling. In recent years more than 156 Burmese pythons have been removed from the park or adjacent lands. Multiple observations of individuals of different size-classes support the establishment of breeding populations of the Burmese python in Everglades National Park. The measured total length for snakes recovered ranged from 65 cm to 427 cm, including hatchling sized animals recovered in the summer of 2004 and 2005. Burmese pythons present a potentially significant threat to the successful ecological restoration of the greater Everglades. Pythons are now established and breeding in South Florida. *Python molurus bivittatus* has the clear potential to occupy the entire footprint of the Comprehensive Everglades Restoration Project, adversely impacting valued resources across the landscape. Burmese pythons are widely bred in Florida and still imported from Southeast Asia as pets. Proposed management and control actions must include strategies for preventing their intentional release. In July of 2005 an Invasive Snake/ Reptile Management and Response Workshop was convened. Workshop participants recommended strategic actions in three broad areas: 1) python control, 2) rapid response to invasive amphibians and reptiles in South Florida, and 3) public outreach and education. Action plans are being drafted and funding pursued.

A Programmatic Overview of the Florida Fish and Wildlife Conservation Commission's Efforts to Prevent, Assess, and Manage Exotic Freshwater Fishes

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More exotic freshwater fishes exist in south Florida than nearly anywhere else in the world. Today 23 exotic fishes have permanently established populations here, 11 more have reproducing populations, and all but six of these 34 species occur somewhere in the southern half of Florida. Moreover, all but one of these fishes were illegally introduced and their presence is universally viewed as being problematic; however, exactly how problematic these species are depends largely on one's values, goals, and objectives.

One reason we have so many exotic fishes in Florida is that most of our freshwater aquatic habitats have been dramatically altered; and, as such, the presence of these exotic fishes may be more symptomatic of, rather than the primary cause of some environmental changes previously attributed to them. For example, the many man-made canals in the metropolitan southeast Florida area potentially provide a receptive habitat for hundreds of exotic fishes from the tropical regions of the world that might not otherwise be able to survive here.

The Florida Fish & Wildlife Conservation Commission has responded to the threats posed by illegally introduced fishes by developing and maintaining multifaceted and interrelated programs focused on the prevention, assessment, and management of exotic fishes, the origins of which date back to the early 1960s. Prevention of illegal releases is of paramount importance, and Florida statutes require persons possessing exotic fishes to obey Commission rules that prohibit the introduction of any species not native to the State; and, persons found in violation of these statutes may be punished with fines of up to $1,000 and one year in jail. Once an exotic fish becomes established, the Commission's priority changes from one of prevention to one of assessment. Assessment of exotic freshwater fishes is the primary responsibility of the Non-Native Fish Project, the objectives of which are to: 1) document their occurrence and distribution; 2) define their life histories, environmental limiting factors, and associations with native species; and 3) develop best fish management practices for these species.

When prevention or elimination of these undesirable but no less available resources is impossible, one management approach we use is to encourage people to fish consumptively for exotic fishes, which helps to reduce their effects while also providing additional recreational opportunities. Another management practice rarely used due to its controversial nature is the legal introduction of an exotic fish for the control of excessive growths of aquatic vegetation or overabundant forage fishes.

Based on the studies conducted by the Commission and others during the past 40 years, I have had to reject the presupposition that the introduction of every exotic freshwater fish represents an inherently catastrophic event; and I have replaced this with one based on the historical fact that these fishes have had real but much less than catastrophic effects. Although not perfect, I believe the existing combination of regulations and programs provides the Commission with one of the most comprehensive and proven approaches for practically dealing with this very serious and complicated issue.

Genetic Analysis of the Diversity, Origins and Pathways of Introduction of Nonindigeneous Swamp Eels (Synbranchidae) in the United States

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Populations of Asian swamp eels have been discovered at four locations in the Southeastern United States: near Atlanta, GA, Homestead, FL, N. Miami, FL, and Tampa Bay area, FL. Swamp eels have many traits that suggest they may have an adverse impact on native aquatic ecosystems, but the number of independent introductions, the pathways of introduction, the current geographical distribution and potential range of the introduced clades, and the identity of the taxa involved in the invasions are unknown. We used both nuclear and mitochondrial genetic markers to study address these questions. We also used these unlinked genetic markers to determine whether hybridization was occurring among independent genetic units. Hybridization among distinct lineages can be problematic because it can reintroduce variability into typically depauperate introduced lineages, and can produce novel invasive genotypes. We analyzed an average of 2,340 bp of sequence including 2 mitochondrial loci (16S and 12S ribosomal RNAs) and two nuclear loci (RAG2 and the LDHA6 intron) from 223 samples including introduced eels, native range eels, commercially available eels (fish markets, pet stores, frozen eels), and additional synbranchid species. Our results show the four introduced populations fall within three well-differentiated clades that roughly correspond to different portions of the Asian range of the synbranchid genus *Monopterus*. A northeastern "A" clade including Japan, Korea, and Taiwan contains the introduced Atlanta population, a central southeastern "B" clade comprised of Vietnam and Malaysia contains the Homestead population, and a "C" clade composed of primarily Chinese samples contains the Tampa Bay and North Miami populations. Both tests of recombination and topological congruence among loci indicate that, to date, hybridization among the three invasive lineages has not occurred. The relationship among samples from North American fish markets (including live as well as packaged frozen specimens) and pet stores suggest a centralized distribution system. It appears eels from across southeast Asia are being collected or cultured in Vietnam and China for export to U.S. markets. Concentrating different genetic units prior to live exportation increases the probability that an introduced individual will match its new environment. In addition to these three major clades, we discovered an additional synbranchid species from central Asia, currently recognized as *Monopterus cuchia*, being sold live in some U.S. markets. The morphologically conservative nature of eels in the family Synbranchidae and the age of the group have led to taxonomic confusion within this group. Analysis of all sampled synbranchid taxa indicates that the genus Monopterus, as currently defined, is not monophyletic. In particular, our analysis indicates the genus *Ophisternon* separates *Monopterus cuchia* from all other sampled *Monopterus*. These findings warrant resurrection of the binomial *Amphipnous cuchia* for this species. It is clear the taxonomy of the family Synbranchidae is in need of revision. Our results document a diversity of lineages present among introduced populations and live fish markets currently in North America. Their genetic diversity suggests that different introduced populations likely differ in life history attributes, potential invasibility (ultimate dispersal and geographic range), and in potential negative effects. These considerations are important and add to the complexity of an ongoing risk assessment of introduced synbranchids.

Diet of the Nonindigenous Asian Swamp Eel *Monopterus albus* (Synbranchidae) in Tropical Ornamental Aquaculture Ponds in West Central Florida

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The nonindigenous Asian swamp eel *Monopterus albus* (Synbranchidae) is reported to be a voracious predator that consumes fish. It is established in west-central Florida where it invades tropical ornamental fish production ponds. The tropical ornamental aquaculture industry in Florida is economically valuable (US$42 million in 2003) and is dominated by the production of small-bodied fishes cultured at high densities in small, earthen ponds. Due to concern about this potential pest species, we collected Asian swamp eels for diet analysis from ornamental aquaculture farms in west-central Florida using backpack electrofishing, dipnets, and seines. Our sampling revealed an increased range within the Tampa Bay drainage and possible invasion of the adjacent Withlacoochee River basin. The density of Asian swamp eels on farms was low and relatively few specimens were collected (N = 71; 94-864 mm total length). Fifty-two percent lacked stomach contents and prey were relatively small and generally few in number. Prey items included amphipods, crayfish, fish, fish eggs, insects, oligochaetes, organic material, plant material, and a tadpole. Insects were the most frequently occurring prey and fish were second. Fish eggs, probably eggs of Asian swamp eels, dominated by number. Fish was the heaviest prey category, closely followed by insects, fish eggs, and crayfish. Only ten fish prey were found in eight Asian swamp eels (including a cannibalized Asian swamp eel). Our diet results were surprising given the highly vulnerable prey fish found in the sampled ponds (estimated at 25-60 fish/m^2) and the claims that Asian swamp eels are "voracious" predators of fish. We conclude that this species represents a low threat to the Florida ornamental aquaculture industry, especially compared to native predators such as wading birds, turtles, snakes, alligators, and eastern mosquitofish *Gambusia holbrooki* or nonindigenous walking catfish *Clarias batrachus*. We recommend that producers continue to employ best management practices, but aggressive control and eradication of Asian swamp eels are not warranted.

The National Park Service – Building a Comprehensive Response to Invasive Species

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The National Park Service (NPS) was created in 1916 (39 Stat. 535) with a mandate to conserve this country's natural and cultural heritage unimpaired for the enjoyment of future generations. That heritage is at risk from the invasion of over 2.6 million acres of invasive plants and hundreds of invasive animals. However, the NPS, through funding from the Natural Resource Challenge and cooperating partners is building a comprehensive response to the threat of invasive species. This presentation will describe the response from strategic planning to case histories of ongoing and successful management of aquatic and terrestrial invasive species.

Building an Aquatic Invasive Species (AIS) Response Through Partnership and Collaboration

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In 2003, the State of Hawaii, through a multi-agency/organization collaboration developed an Aquatic Invasive Species Management Plan. This management plan outlines goals and objectives in managing invasive species and identifies priority tasks needed to accomplish those. A 15-person advisory group, comprised of individuals from 8 different agencies and institutions, advises an AIS Coordinator whose role is to manage the execution of these tasks. In addition, as part of the management plan an Aquatic Invasive Species Response Team has been formed to provide a more rapid response to new introductions. This team has enabled the agency to devote considerable time and resources to a wide range of projects with numerous partnerships. These partnerships include, among others, the University of Hawaii, the Hawaii Department of Agriculture, the Bishop Museum and the National Park Service. The additional, dedicated manpower allows for increased monitoring capabilities and better control efforts. The team is utilized regularly for an algae control project being headed by the University of Hawaii and is organizing a multi-agency eradication project of *Carijoa riisei* ("Snowflake Coral") in Port Allen, Kauai. The Hawaii Department of Agriculture and the AIS Team have worked together to eradicate a corallimorph population that was unlawfully introduced and the National Park Service has utilized the team for invasive algae clean-up in the Kaloko-Honokohau National Park. In addition, the AIS Team assists with community outreach and education projects. In the future, the Coordinator and the team will be part of a state-wide reporting system of invasive species which will facilitate the eradication of introduced species before they can become invasive populations. An increasing recognition throughout the state of the threat that aquatic invasive pose at all levels, together with increased funding from the state has dramatically increased the time and resources that are put to aquatic invasive species management.

Cultures in Conflict: The Complexities of Invasive Species Management

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Invasive species management has often been criticized for being xenophobic, prompted by paranoia, and intended to scare the public. Thus far, the responses from ecologists and policy makers have tended to adopt the stance that the criticisms stem from lack of understanding of invasion ecology, and knowledge about the ecological and economic impact of invasives species.

This paper focuses on the study of an invasive species in a society where cultural values and perceptions are in conflict with standard scientific and governmental approaches to invasive species management. The case history chosen for analysis is the invasion of the Chinese mitten crab (*Eriocheir sinensis*) in the San Francisco Bay system in California.

In the San Francisco-San Joaquin Bay/Delta in California, U.S., the Chinese mitten crab has rapidly spread along the riverbanks. Considered a delicacy in Asia where only the well heeled can afford, and a black market values in the U.S. reported to be almost $40/lb, the Chinese mitten crab stirs a very different response from the scientific and political communities.

Their threat to biodiversity, the ecosystem, commercial and recreational fisheries, and water supply has caused ecologists to declare it an invasive species, and Californian regulators to declare it "illegal to import, transport, or possess live mitten crabs". Crabs caught in water intake pipes are cleared and destroyed by the thousands.

Despite its illegal status and the high ecological, social, and economic costs associated with the mitten crab, attractive black market values of mitten crabs continue to provide strong incentives for smugglers.

The lack of support from the Asian community in San Francisco for the management approach towards the mitten crab stems less from ignorance about the issue or ecological concern, than from a much more fundamental difference in cultural values, and worldview.

Based on interviews, ethnographic research, and discourse analysis methods used to examine the ways in which regulators, scientists, and members of the Asian community in California frame their narratives of the issue, this study looks at recurrent themes that reveal entrenched perceptions and sentiments. It discusses the efficacy of current management policies in light of these different standpoints, and considers how culture may have a role to play in invasive species management.

Geographical Eradication of an Alien Octocoral, *Carijoa riisei*, in Hawaii

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Carijoa riisei, Snowflake coral, is an invasive soft coral from the Caribbean and believed to be introduced by means of a maritime vector. Discovered in Pearl Harbor, Oahu, Hawaii in 1972, it has now spread throughout the main Hawaiian Islands and has recently been found to smother black coral in the Auau channel between Maui and Lanai. *C. riisei*'s optimal habitat includes shaded environments with moderate to strong water flow where it may overgrow and smother corals and other benthic fauna. This coral has a competitive advantage in its optimal habitat due to multiple reproductive strategies and a high growth rate.

Although *C. riisei* has been spread throughout the main Hawaiian Islands, it has only been sighted in a few discrete locations around Kauai and Niihau and thus may present an opportunity to conduct a geographical eradication of this invasive coral. Of the few sightings of *C. riisei*, the largest and only reproductive population is located in Port Allen, Kauai. Since *C. riisei* has not become established in the Northwestern Hawaiian Islands (NWHI), the eradication of *C. riisei* from Port Allen may stop its dispersal further north.

In Port Allen, *C. riisei* inhabits approximately 60% of 663 pilings under a commercial pier. Fortunately, *C. riisei* has not been found to inhabit other structures in this harbor. In order to eradicate *C. riisei* from this harbor, the Division of Aquatic Resources (DAR) engineered a method to smother the coral on the pier pilings. This method uses plastic sheeting to wrap the pilings with the goal of smothering the benthic fauna and subsequently killing *C. riisei*. The plastic is left in place for a minimum of 60 days after which time the plastic is removed and disposed. Preliminary trials of this method have resulted in 100% effectiveness.

DAR has begun to wrap all 663 pilings in Port Allen. It is estimated to take 10-14 days of diving using 18-22 divers, a couple hundred roles of plastic, several thousand cable ties, and several hundred roles of PVC tape. The cost is estimated to be approximately $40,000 in supplies and travel plus labor costs. Results and lessons learned from this effort will be presented.

Impact of the Invasive Crayfish, *Procambarus clarkii*, in Mediterranean Wetlands and Proposals for its Mitigation

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Since the 1990s, the red swamp crayfish, *Procambarus clarkii*, is extensively diffused in several Italian water bodies where it threats biodiversity and ecosystem functioning. Here we propose a protocol of intervention aimed both at mitigating the impact of this species and at promoting its appraisal as a "safe" food item.

Invasive, Predatory Fish Removal in a Large Desert River: Feel Good or Effective Project, Verde River, Arizona, USA

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Native fishes in the upper Verde River have declined dramatically since 1994 and recruitment of several of the longer-lived, extant species is almost absent. Studies were initiated in autumn 1999 to commence removal of mostly larger, nonnative, predatory species from three 1 km reaches of river. Success of the project was based on responses of the respective species' young-of-year (YOY) recruitment into the population. Four years of twice-a-year removal efforts in these 1 km reaches have failed to produce a positive response. Recruitment of YOY Sonora (*Catostomus insignis*) and desert sucker (*C. clarki*) and roundtail chub (*Gila robusta*) did not increase in the four-year period. By contrast, total numbers of nonnative individuals removed steadily increased. The top nonnative predator, smallmouth bass (*Micropterus dolomieui*), was the most abundant species removed at all three sites, yet became both more numerous and smaller in mean size from 1999 to 2003. Lack of success in this pilot project appears to result from: 1) lack of barriers to immigration into removal reaches, 2) insufficient intensity and extent of removal to achieve projected response, 3) habitat complexity in form of increased streambank vegetative cover, and 4) stable base flows and lack of flooding that appeared to favor nonnative fish production. In retrospect, this was probably another "feel good" versus effective project. A proposal will be presented to increase removal efficiency and conceivably benefit native fishes in the upper Verde and its tributaries while at the same time delineate 1) size of stream versus effectiveness, 2) mechanical versus chemical treatment, 3) removal intensity and extent versus effectiveness, and 4) possible impact of non-piscine predators.

Home vs Guests – The Game is on Against Aliens

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When it comes to light that an alien species was introduced into an environment it is crucial to rapidly gain knowledge on its colonisation potential if robust risk assessment needs to be developed. It is even more relevant for alien fish species as their potential for invasion is often understood too late due to the nature of the aquatic environment. Here we studied the dispersal of the most invasive fish species in Europe, the topmouth gudgeon *Pseudorasbora parva*, from an original source of introduction into the downstream river system. We subsequently looked at the potential for biological resistance from the native predator community. The rate of displacement from the source population into the receiving stream appears to follow a diel pattern, with generally higher rates at night than during the day. We found a large density of brown trout and chub in the stream that preyed on *P. parva*, which may have had an impact on the number of fish and their distribution in the downstream system. However, we did not find that this represented sufficient biological resistance against the establishment of this alien species in the river. However, high stocking density of native predators below an alien introduction may help to slow down an invasive species during the establishment phase but is unlikely to be sufficient when the alien fish population is already well established.

Case Studies on the Eradication of the Invasive Cyprinid Topmouth Gudgeon *Pseudorasbora parva* from Fisheries in England

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The topmouth gudgeon *Pseudorasbora parva* is a cyprinid fish from Asia that is regarded as an international pest species due to its high ability to successfully invade and colonise new waters. Rarely attaining lengths over 80mm, the species has successfully dispersed to, and colonised, many waters across Europe since 1960. Dispersal mechanisms included liberation of aquarium specimens (it is an ornamental species), contaminated batches of fish introduced into waters for fishery enhancement and natural dispersal. The species has now reached England and is present in at least 24 fisheries. This is of concern, for the life history traits of topmouth gudgeon facilitates colonisation of new waters by providing considerable competitive advantages over the native fish species of England. Furthermore, recent work has shown it is a vector for an emerging infectious disease that may inhibit the reproduction of native fishes.

Minimising the distribution and dispersal of topmouth gudgeon in England requires a range of control measures. These range from national policies on regulating fish introductions to topmouth gudgeon eradication programmes at individual fisheries. These are discussed in this paper through the presentation of two case studies on eradicating topmouth gudgeon from recreational fisheries. The first concerns a lake in the Lake District of Northwest of England, an area of outstanding natural beauty whose glacial lakes have impoverished fish populations comprising few species, some of which are rare and endangered. To prevent dispersal of topmouth gudgeon into these lakes, an eradication programme, incorporating application of a piscicide, was implemented in February 2005. To date, evaluation suggests that the exercise has successfully eradicated topmouth gudgeon from the lake and prevented their further dispersal and associated impacts.

The second eradication case study concerns a lake connected to a river catchment in the Midlands of England. Should topmouth gudgeon disperse from the lake, then there is the risk of the species colonising over 150km of a river that has a high conservation designation and comprises recreational fisheries of high social and economic value. The eradication exercise was initiated in August 2005 and will involve completely draining the lake and applying lime, after which the lake will be left dry for 6 months. This approach was used due to the additional presence of two novel fish parasites discovered on the resident fish population.

The outputs of these case studies are then compared, with discussion in the context of fishery management, the desire to minimise non-native fish distribution and the fish movement industry of England.

Directed Extinction of Exotic Fish Populations in the Wild Using a Fish Bearing Multiple Y Chromosomes

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The United States is host to a wide variety of exotic aquatic species that were introduced and established as a result of human activities. In the Great Lakes, the ruffe, sea lamprey, and round goby represent exotic species that were introduced as a result of shipping and have subsequently become established throughout the region. These species have produced adverse effects upon native fish populations and the collapse of native fisheries. In Florida and Texas, exotic armored catfish introduced through the aquarium trade contribute to river bank erosion as a result of their burrowing activities. Another exotic species introduced to Florida, the walking catfish, negatively impacts the aquaculture industry. Once established, certain exotic fish species are virtually impossible to eradicate, leaving native ecosystems irreversibly altered. Exotic species of fish such as Asian carp, sea lamprey, round gobies and tilapia are thus expected to have long lasting and unavoidable negative consequences upon native U.S. ecosystems.

A means of inducing extinction of an exotic population is proposed using a genetic approach to shift the ratio of male to females within a population. In the proposed strategy, sex-reversed female fish containing two Y chromosomes (Fyy) are introduced into a normal fish population. These Fyy fish can be produced through standard aquaculture breeding techniques that employ hormone-induced sex reversal combined with gynogeny. A feminized YY exotic fish (Fyy) has only Y chromosomes to pass on through its gametes, and would be expected to produce only male progeny when mated to a normal male (Mxy). If introduced into a wild population, Fyy fish would thus have an impact to reduce the number of females produced as a result of matings with normal males. Further, the males produced from Fyy matings would consist of 50% Mxy fish and 50% Myy fish. The Myy fish would go on to further skew the sex ratio of the population by producing only male progeny when mated to normal females. Fyy fish thus have the effect to decrease the production of normal females (Fxx) in the population, and if added in sufficient numbers, could potentially reduce the production of new females to zero.

We have developed a mathematical model to describe the effects of the addition of Fyy fish to a population of normal Mxy and Fxx fish. In the model, the frequency of each of the four expected genotypes of fish in the simulated population (Fxx, Fyy, Mxy, and Myy) is represented by a differential equation. The equations take into account birthrate, death rate, and a fixed carrying capacity of the system. Using computer generated simulations we are able to determine parameters that lead to extinction. Our results indicate that the continuous introduction of a relatively small number of Fyy females to the normal population leads to extinction of the exotic fish over time.

The Rapid Establishment of the Indo-Pacific Lionfish, *Pterois volitans/miles* complex, in the Western North Atlantic

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Less than a decade after the first observations off Florida (USA) the Indo-Pacific lionfish (*Pterois volitans*) are now found in similar abundance as native groupers. We quantified lionfish and native grouper (epinepheline serranids) abundance from Florida to North Carolina in two separate studies. In the first study we conducted SCUBA diver visual transect surveys at 17 different locations off the North Carolina coast in water depths of 35 to 50 m. In the second study, we conducted 27 ROV transect surveys at five locations from Florida to North Carolina in water depths of 50 to 100 m. Lionfish were found to be second in abundance only to scamp (*Mycteroperca phenax*). Lionfish were found in higher abundance in the shallower North Carolina SCUBA surveys ($\bar{x}$ = 21.2 hectare-1) than in the deep water ROV surveys ($\bar{x}$ = 5.2 hectare-1). There were no significant differences in abundance between lionfish and other groupers surveyed. This invasion was likely facilitated by a combination of lionfish life history attributes such as broad larval dispersal mechanism, generalist diet and venomous spines combined with a disturbed environment, which is largely over-fished of mid-level competitors. The abundance of lionfish will likely continue to increase, with impending ecological effects unknown.

Genetic Analyses of the Western Atlantic Lionfish Invasion

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We have been analyzing genetic data in order to better understand the source and characteristics of the Western Atlantic invasive lionfish population. As part of this work we developed primers for amplifying and sequencing a majority of the mitochondrial-encoded cytochrome-b gene from lionfish. To date, these primers have been used to generate cytochrome-b gene sequences (or haplotypes) from 258 lionfishes, including 170 Western Atlantic and 88 native range specimens. Our initial finding have shown that: 1) two closely related sister species *P. volitans* and *P. miles* are present within the Atlantic but in very different proportions with 93.5% of collected specimens being *P. volitans*; 2) the haplotype network generated for *P. volitans* specimens from the native range of the species is relatively complex and contains 28 different haplotypes that show a geographic trend in structure, and 3) the haplotype network generated for *P. volitans* specimens from the Western Atlantic in contrast consist of only three total haplotypes, with the vast majority of specimens (95%) sharing the same one. Additional *Pterois* species are being sequenced in order to clarify the status of *P. volitans* and *P. miles* as closely related sister species, and verify the geographic structure seen in haplotype networks of native-range *P. volitans* specimens.

Reproductive Biology and Invasiveness of the Lionfish, *Pterois volitans,* in the Western Atlantic, USA

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The recent introduction of lionfish into the western Atlantic has raised many questions and ecological concerns. Understanding the scale of these concerns, however, is dependent on the lionfish population growth rate in its new habitat. Lionfish population growth will likely controlled by reproductive biology and thermal habitat availability. For this reason, we are describing the reproductive biology of the lionfish, *Pterois volitans*, in efforts to provide information for predicting lionfish population growth in the western Atlantic. Laboratory and field collected specimens have provided information regarding size at maturity, sex ratios in the wild, and spawning seasonality in the Atlantic. Laboratory rearing experiments suggest that lionfish are asynchronous sequential spawners releasing multiple eggs balls during each spawning event similar to other scorpaenids. Ongoing research to produce lionfish larvae will provide much needed information on temperature tolerance of lionfish larvae, a factor likely to limit lionfish recruitment in the Atlantic during winter months. These efforts will also provide a much-needed description of *Pterois volitans* larvae, which can be used for monitoring lionfish abundance during regular oceanic ichthyoplankton surveys. This comprehensive assessment of lionfish reproduction and early life history is being used to develop a stage-based matrix model for prediction of lionfish population growth in the Atlantic. Lionfish present a unique opportunity to study a nonindigenous marine reef fish early in its introduction. Given the reproductive strategy and early life history of the lionfish, increases in lionfish densities along the reef habitats of the U.S. southeast coast is expected, thus, providing a unprecedented opportunity for developing a predictive population growth model for invasive marine reef fishes. The methods and model developed in this research will be applicable to other potentially invasive marine reef fishes and could be used as a predictive tool for assessing relative risks associated with the importation of exotic reef fishes into the U.S.

Age and Growth of Lionfish, *Pterois volitans*, Inhabiting the Offshore Waters of Onslow Bay, North Carolina, USA

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An age and growth study of lionfish, *Pterois volitans*, collected from Onslow Bay, North Carolina has been undertaken. All three pairs of otoliths (sagitta, asteriscus, and lapillus), and the first and second dorsal spines have been removed from the lionfish samples (n = 153). We selected the sagittal otolith for aging because it was much larger and easier to handle than the asteriscus or lapillus. When viewed whole, the sagittal otoliths were relatively thick and very opaque. No annuli could be detected. The otoliths were small and required embedding in epoxy to be sectioned. Initially, one 2 mm section from the core area was taken from each otolith and then polished to remove the scratches and find the core. Most of the otolith sections did not appear to have any annuli, or one just starting to form on the margin of the otolith from a fish captured in June. One large specimen (43 cm TL) caught in March did appear to have two annuli with a large translucent zone after the second annulus, suggesting that the individual would be three years old that year. We will finish the thin polishing of the sections and count daily rings to determine if the specimens are under a year old.

The spines of the lionfish are very thin and fragile, much like a hypodermic needle. We had to embed the spines in epoxy to give them some stability for sectioning. Upon viewing the spine sections with reflected light under a dissecting microscope, no discernable structure could be found. We are sectioning a few more spine samples to determine if they are a suitable for aging.

Initial analysis of the samples suggests that lionfish off the coast of North Carolina have not been there for very many years. The oldest fish in the sampled population thus far is three years old.

Predatory Impacts of the Indo-Pacific Lionfish in the Atlantic Waters of the Southeast United States

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The Indo-Pacific Lionfish (*Pterois volitans/miles* complex), a venomous predatory fish, is established (reproducing and dispersing) along the southeast shelf of the United States. Within the last four years lionfish have spread from Florida to Cape Hatteras, North Carolina and Bermuda. There have been very few fish invasions into open marine systems but one exception is the bluestripe snapper, *Lutjanus kasmira*, which was intentionally introduced into Hawaiian waters in the 1950s. Presently, *L. kasmira* is the second most abundant fish both in numbers and biomass over hard substrata in Hawaii, and stomach content analyses suggest that this introduced species has adversely affected many populations of Hawaii's native species. In freshwater environments, introduced fishes have been implicated in the decline and displacement of native fish populations, including community level effects that extend beyond the replacement of native fishes. In an effort to quantify the food web consequences of the lionfish invasion to the native rocky reef community in the southeast United States, stomach content and stable isotope analyses were undertaken. Carbon and nitrogen isotopes can provide insight into the sources of primary production supporting lionfish, and nitrogen isotopes are useful indices of trophic level and can be used to trace ontogenetic changes in diet. During June-August 2004 we collected lionfish during daylight hours from 17 different locations in Onslow Bay, NC. Following collection at depths from 100-150 feet, individual specimens were placed in plastic bags to prevent loss of regurgitated stomach contents during ascent, and mouth and gill rakers were examined for regurgitated prey at the surface. Stomachs were removed immediately following collection and preserved in 95% ethanol. Muscle tissue was removed and frozen for isotope analysis. Despite the suggestion that lionfish are nocturnal, most lionfish were collected with full stomachs. Prey items in the stomachs of lionfish are being identified to the lowest practical taxonomic level, counted, measured, weighed, and the volume of prey categories is being determined by displacement. Ongoing analyses of the stomach contents from 87 fish suggest a generalist carnivorous diet including decapod crustaceans, cephalopod and bivalve mollusks, and prey from a variety of fish families including members of the Pomacentridae, Labridae, Scaridae, Blenniidae, Bothidae, and Monacanthidae. Despite a poor understanding of the processes that control invasion success in marine systems, available evidence suggests that the most successful fish invaders appear to be piscivorous or omnivorous and ecological generalists. Furthermore, when examining the long-term integration of invasive species into existing communities, piscivores are believed most capable of altering the communities, which they invade.

Parasites of the Invasive Red Lionfish, *Pterois volitans*, Off the North Carolina Coast, USA

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From July 15-24, 2005, NOAA scientists aboard the research vessel NANCY FOSTER performed a study of the ecological roles of the non-native red lionfish, *Pterois volitans*, in North Carolina waters. During this research expedition, 20 lionfish were collected by scuba divers and brought to the ship alive for the purpose of studying their parasites. These fish were collected between Cape Fear and Cape Lookout, North Carolina at depths of 95 to 150 feet, brought back to the Beaufort Marine Laboratory (Beaufort, North Carolina) and kept in a closed seawater system. Over a period of 9 days, lionfish were killed individually with tricaine methane sulfonate, measured to the nearest mm, weighed to the nearest gram, and examined for external and internal metazoan parasites. The total length of these fish ranged from 16.9 to 43.5 cm (mean = 22.4 cm), and the weight ranged from 62 g to 1.38 kg (mean = 207.4 g). A stomach trematode (Platyhelminthes: Trematoda) was the most common parasite found; its prevalence was 60% and the mean intensity of infection was 3.7 worms per fish (range 1-11 worms per fish). Other less common parasites found were larval nematodes in the stomach and liver, a single gill metacercaria (a larval trematode), a single fish with 2 larval trypanorhynchs (Platyhelminthes: Eucestoda: Trypanorhyncha), unidentified cysts in gills, and a single specimen of *Argulus* sp. (Arthropoda: Crustacea: Branchiura) on the skin. No monogeneans (Platyhelminthes: Monogenea) or copepods (Arthropoda: Crustacea: Copepoda) were found. Completed laboratory work will reveal 1) what parasite species infect these non-native fish hosts, and 2) the prevalence and mean intensity of infection of each parasite species found. Then we will determine if the parasite species found are naturally occurring parasites associated with native Atlantic fishes, or if Atlantic lionfish are infected by parasite species you would expect to find in the native habitat of the red lionfish, i.e., the Pacific and Indian oceans, or the Red Sea. If the latter hypothesis is true, there is a great risk of introducing non-native parasites to native Atlantic reef fishes (e.g., snappers and groupers), which could have a deleterious effect on their populations. However, the fact that lionfish in the Atlantic have so few parasites suggests that they are free of their natural parasites, which could partly explain their success in spreading their range all along the southeastern coast of the United States.

Implications for Controlling Bighead Carp from Stock-recruit Modeling of Population Dynamics in the Illinois and Mississippi Rivers

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The bighead carp (*Hypophthalmichthys nobilis*) is one of four species of carp that have been imported into the U.S. from Asia. Bighead carp were imported into the southern U.S. in the early 1970s to improve water quality in aquaculture ponds, and to possibly be marketed as food fish. Bighead carp escaped into the Mississippi River Basin, and established self-sustaining populations there. Bighead carp have been captured in the Great Lakes Basin, but there is no evidence of successful recruitment there. We studied the population dynamics of bighead carp in the LaGrange Reach of the Illinois River and Pool 26 of the Mississippi River to understand how to control and manage populations. Bighead carp recruitment to the 1 to 3-month stage in the LaGrange Reach and Pool 26 varied by a factor of 39 in LaGrange Reach and 8.5 in Pool 26 during 2001-2004, while abundance of bighead carp > 470 mm in assessment gill nets varied by a factor of 61 in LaGrange Reach and 4 in Pool 26. The Ricker model derived from the stock and recruit data for the LaGrange Reach and Pool 26 explained 85% of the recruitment variation in those areas, and was validated using two different approaches. The modeled functional relationship indicated that optimum stock size was about 0.22 adults/unit of fishing effort in assessment gill nets, and predicted poor recruitment below a stock size of about 0.09 adults/unit of fishing effort. Recruitment of bighead carp in the LaGrange Reach and Pool 26 was negatively correlated with stock size, and the coefficient for stock size in the stock-recruit model was significant, so those results were interpreted to mean that compensatory, density-dependent mortality affected bighead carp recruitment. Most of the variability in recruitment of bighead carp was explained by variation in stock size, so efforts to control populations in the LaGrange Reach and Pool 26 should focus mostly on reducing stock size. The results of this study indicated that stock size should be reduced to less than 0.09 adults/unit of fishing effort in assessment gill nets to effectively control recruitment. That level of adult abundance should be the target maximum for stock control efforts that employ netting or other approaches to reduce adult abundance. Stock-recruitment models should be developed for every invasive fish. Those models can incorporate biotic and abiotic variables, and result in implications for managing some of the variables that most control recruitment and adult stock abundance.

Meeting New Challenges in Hydrilla (*Hydrilla verticillata*) Management in Florida

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The submersed aquatic plant hydrilla (*Hydrilla verticillata* L.F. Royle) was introduced into Florida as an aquarium curiosity in the early 1950s. Shortly afterwards, it found its way into south Florida flood control canals and then into public lakes and rivers throughout the state. Hydrilla was reported in 198 (42%) of Florida's public lakes and rivers in 2004.

Hydrilla problems relate to its rapid growth (up to 10 cm per day), multiple reproductive and survival mechanisms (above and below ground turions, fragmentation, stolons), Florida's shallow, nutrient rich waters (2-5 m average depths), and nearly year-round growing season. Hydrilla can expand from pioneer colonies to fill water columns and form dense surface mats covering thousands of contiguous hectares in a matter of one to two years. Florida public waters serve a variety of functions including; fish and wildlife habitat, recreation, navigation, and potable water and irrigation supply. Perhaps most importantly, most Florida public waters are interconnected, serving as flood control conduits. When hydrilla covers the water surface, it interferes with all of these uses and therefore must be controlled.

Early detection and rapid response are extremely important in hydrilla management and more than 100 pioneer hydrilla colonies were eradicated from Florida public waters during the past decade. Sterile grass carp are stocked in small self-contained lakes and contact-type herbicides are applied to control small hydrilla populations. However, once it establishes over hundreds or thousands of hectares, eradicating hydrilla has proven nearly impossible and management is expensive, temporary, and extremely difficult.

From the mid-1980s until the early 2000s, most large-scale hydrilla control was accomplished using the slow-acting, systemic herbicide, fluridone. Exposure to fluridone for 60-120 days at rates as low as 3-5 ug/l selectively controlled hydrilla among nearly all native plant species for periods of up to 18-24 months until regrowth occurred from sprouting turions that can number in the millions per acre in the sediments. In 2000, researchers confirmed managers' observations that hydrilla was developing an increasing tolerance to fluridone herbicide, and that increasing amounts of fluridone were required to control hydrilla.

This increasing tolerance surprised scientists and managers in that it is the first case of proven resistance to a bleaching herbicide. Moreover, hydrilla represents the first example of a purely clonal population developing a somatic mutation that allowed the spread of a resistant clone. Apparently, controlling greater than 95% of the susceptible hydrilla during a fluridone application creates open water for tolerant hydrilla clones to rapidly expand within waters and to be transported to other waters – even those that have never been treated with fluridone.

Managing Invasive Species Through Partnership for Healthy Coastal Ecosystems

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Protecting, conserving, and restoring the ecosystems and habitats in the southeastern U.S. for the continuing benefit, use and enjoyment of all Americans is the goal of 21 state and federal agencies and other organizations joined together by memorandum of understanding as SARP – the Southeast Aquatic Resources Partnership. After years of striving to achieve this goal individually, the partners have pooled expertise and resources to work together within the region in six areas: 1) public use, 2) fishery mitigation, 3) imperiled fish and aquatic fish species recovery, 4) interjurisdictional fisheries, 5) aquatic habitat conservation, and 6) aquatic nuisance species. In area 6, SARP's first project involves helping each of its 13 member states (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas) develop and implement state aquatic invasive species (AIS) management plans. The partnership facilitates plan development shaped by awareness of common natural communities, watersheds and issues, and the possibilities of regional cooperation to achieve state AIS management objectives.

The southeast region of the United States is one of the most species-rich areas in the temperate zone because of diverse environments and some evolutionary isolation (Mac, Opter, Puckett Haecker and Doran, 1998, p. 255). From Virginia to Texas, the Ohio River to the Gulf of Mexico, it is dominated by aquatic ecosystems that are part of 47% of the nation's wetlands and 78% of its coastal marshes (Keeland, Allen and Burkett, 1995, pp. 216-218). The region's 70 major river basins and 26,000 miles of shoreline provide habitat for 65% of the nation's freshwater fish species (Mac, Opter, Puckett Haecker, and Doran, 1998, p. 296). Most of these ecosystems are not restricted to state boundaries, yet their care is the major responsibility of one or more state political entities.

More aquatic nonindigenous species have succeeded in this region than any other, possibly because of the temperate and subtropical climate, abundant surface water, and more than a thousand miles of coastline dotted with four of the top 10 international shipping ports in the country (Benson, Fuller, and Jacono, 2001 p. 5). Roughly half of all non-native fish species introduced into the southeast became established (Benson, Fuller, and Jacono, 2001, p. 7). The result is not always negative, but it always involves change in some way – in the ecosystem, the biodiversity of the area, and/or the economy.

Under normal circumstances, maintaining water, nutrient, and energy cycles is a challenge to all ecological managers. They balance decisions to meet diverse ecological and economic goals, and often use biodiversity as an ecosystem health indicator. AIS intensify the challenge because they are seldom identified before they cause change, and they can be introduced deliberately and accidentally at any time.

For these reasons, an invasive species is seldom fully eradicated. More often, management is limited to control or containment, and the native ecosystem is allowed to change – a costly alternative for the habitat, plant and animal communities, and the people who depend upon them. Coastlines have been changed by erosion-causing invasive animals such as nutria (*Myocastor coypu*) (Louisiana Department of Wildlife and Fisheries, 2003). Coastal estuaries in other regions have been weakened when an invading marsh grass such as *Spartina alternaflora* changes the sediment accretion rate and alters ebb and flow necessary to a particular ecosystem (Lance, L., 1995, observed 2/9/05; Little, C. 2000, pp. 18-21) or, when a plant like purple loosestrife (*Lythrum salicaria*) out-competes native plants that provide good nutrition for birds and other wildlife (Ontario Federation of Anglers and Hunters, 1996).

Without regional management, change to the southeastern ecosystems by other species is likely. AIS succeed in areas that have a similar-to-origin climate, are recently disturbed, have low natural diversity, a relatively simple food web, are anthropogenically disturbed, and that have no likely predators or species with a similar morphology (Williams and Meffe 1999, pp. 6-7). Coastal areas and estuaries are naturally disturbed, low-diversity systems made more vulnerable in this century by anthropogenic activities such as shipping, industrial development, and urbanization (Ray 2005, p. 6). Some of the most vulnerable of these are in Louisiana and Florida, and several of the nation's largest international shipping ports dot the Gulf of Mexico and South Atlantic coastlines. Invasive species management, focusing first on prevention, is essential in this region.

Timing and communication are the keys to achieving a management plan in each southeastern state. SARP secured a grant to fund a full-time coordinator for the group, and each member state appointed an individual to lead the state effort during 2004-2007. These individuals opened communication with one another by telephone and e-mail, and are using SARP membership, as well as participation

in the Gulf and South Atlantic Regional ANS Panel and the Mississippi River Basin Panel on ANS to achieve the project goal. Open communication encourages similarities in management plan format, cooperation between neighboring states, and improved effectiveness of control and prevention measures.

Most of the states are forming stakeholder work groups to collaborate on the plan's content, and most are following online guidelines provided by the National Aquatic Nuisance Species Task Force. Completion and acceptance of a plan by the national task force opens the door for each state to apply for federal assistance in implementing the management plan.

Through a variety of mechanisms, the work groups are identifying native and problem species, new infestations, and possible invasion pathways within their state boundaries. They are sharing information with their counterparts who share responsibilities for common watersheds, wildlife, fish and/or plant species. Work will continue far beyond 2007. A management plan identifies the situation and lists needs for prevention and control. It sets priorities and encourages or provides mechanisms to overcome overlapping or conflicting jurisdictions. Implementation is ongoing.

This project's goal is completion of as many (if not all 13) management plans by summer of 2007. This paper will report on progress to date towards that goal and on selected AIS prevention and control successes and challenges resulting from the partnership. Examples of overlapping jurisdictions for species and pathways will also be reported.

Invasive Species Initiatives in the Galveston Bay Estuary: Risk Assessment, Research, Management and Outreach

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Issues related to invasive species and their associated impacts are of increasing concern to resource managers and policymakers in coastal areas around the U.S. The Galveston Bay Estuary is a 600 square mile bay system located on the Upper Texas Coast. Galveston Bay is home to the Houston-Galveston metropolitan region with nearly five million residents and numerous potential invasive species pathways, including shipping ports, live seafood markets, and thriving aquarium and horticultural trade industries. The Galveston Bay Estuary Program (GBEP) and its network of partner organizations are involved in a number of invasive species initiatives including, comparative risk assessment, public education initiatives, invasive species control efforts, and monitoring studies in area bayous.

In 2004, the GBEP and the Houston Advanced Research Center (HARC) completed a comparative risk assessment of invasive species of the Lower Galveston Bay Watershed. The risk assessment resulted in a preliminary list of 296 current and potential aquatic and terrestrial invaders for the Lower Galveston Bay Watershed. Of those, 84 were ranked by local experts according to the risk the species pose to the health of Galveston Bay ecosystems and to the human uses of those systems. Of the 84 species ranked, the top 23 species (13 plant species and ten species of animals) were then assessed according to available management resources. Results of the risk assessment were used by the GBEP to focus resources on invasive species management, research, and public outreach initiatives.

The GBEP, the TPWD, and HARC are working on two public education initiatives. The first is a poster describing the top twelve prohibited aquatic nuisance species that have been encountered in live seafood markets and restaurants in the Houston area. The TPWD poster will be distributed to live seafood markets and aquarium stores. The second project is an invasive plant pocket field guide describing 40 invasive plants of the Lower Galveston Bay Watershed. The field guide will be distributed in hard copy and electronic form to homeowners and horticultural trade representatives.

Galveston Bay invasive species research initiatives are both species and habitat specific. GBEP's species research currently focuses on the environmental requirements, distribution, and impacts of channeled applesnail and deep-rooted sedge. TPWD recently completed a study of the distribution, age, and population genetics of aquatic nuisance species in three Houston area bayous.

GBEP and partners including state and federal agencies, local municipalities, and local nonprofit organizations are involved in a number of invasive species control activities. Efforts are underway to eradicate stands of Chinese tallow and Brazilian peppertree as well as restore impacted wetland and coastal prairie habitats.

Invasive species represent a considerable risk to the natural and human communities that coexist in the Lower Galveston Bay Watershed. Control of these species is a financial burden on resource management agencies and individuals. GBEP and its wide network of partners are working to address invasive species issues through changes in public policy and actions of individual citizens.

A Test of the Impact of Hydrilla Introduction on Biodiversity in Florida Lakes

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The addition of exotic species to ecosystems often has been associated with the decline in species richness and diversity of native flora and/or fauna. Hydrilla Hydrilla verticillata is native to Asia and was first observed in the United States, specifically in Florida in the late 1950s. Since then, hydrilla has spread across the U.S. resulting in a multitude of problems for water-related recreation and navigation. Although accused of adversely affecting freshwater biota, few studies have compared biodiversity of lakes with hydrilla to those without. We compared species richness and diversity of fish, aquatic birds, and aquatic plants for lakes with and without hydrilla from a sample of 45 Florida lakes. Species richness for aquatic birds, and plants were significantly greater ($p<0.1$) in lakes with hydrilla present ($N=12$) than at lakes without hydrilla ($N=33$). However, lakes with hydrilla present were also significantly greater in surface area and when lakes of similar size were compared, species richness of fishes did not differ although richness for aquatic birds and plants was still greater for lakes with hydrilla. Results indicate that species richness and diversity of fish, aquatic birds, and aquatic plants may not be adversely affected by occurrence of hydrilla for Florida lakes.

Invasion of *Melaleuca quinquenervia* Alters Soil Microbial Population Dynamics

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Melaleuca quinquenervia is an invasive Australian tree that was introduced into the Florida Everglades in the early 20th century. Due to its fire adapted nature and copious seed production, melaleuca is able to out-compete and replace many native species thereby potentially altering the underlying soils. In February 2005, fourteen plots were established in two areas: an invaded area dominated by mature melaleuca trees with an under-story carpet of even-aged saplings and a non-invaded area dominated by mature cypress trees. Four soil samples were taken in each plot and separated at two depths: 0-5 cm and 5-15 cm. Laboratory analyses include measurements of pH, bulk density, total carbon (C), nitrogen (N), and phosphorous (P), microbial biomass C, N, and P, and N and P mineralization. A phospholipid fatty acid profile of soil microbes will be completed and any community-level differences will be evaluated using principle components analysis.

Preliminary results reveal microbial biomass values were consistently higher in the non-invaded soils as compared to soils dominated by melaleuca. Microbial biomass carbon was 17% lower in the invaded soils for the 0-5cm soil depth and 25% lower for the 5-15cm depth. Microbial biomass nitrogen (MBN) and phosphorus (MBP) values followed a similar pattern. MBN was 29% lower in the invaded soils for the 0-5cm soil depth and 48% lower for the 5-15cm depth. MBP was 38% lower in the invaded soils for the 0-5cm soil depth and 53% lower for the 5-15cm depth. These results and additional biogeochemical and microbial population analyses will be used to test three central hypotheses: lower substrate quality in melaleuca litter will 1) lower microbial biomass in invaded soils; 2) lower mineralization capacities in invaded soils; and 3) there will be a shift in the microbial species composition and an overall reduction in the microbial biodiversity in the invaded soils.

Limitation of Giant Salvinia (*Salvinia molesta* Mitchell) by Nutrients and pH

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Giant salvinia (*Salvinia molesta* Mitchell), a native of South America, is an invasive floating aquatic fern. Giant salvinia has been a detrimental noxious pest in Australasia, Africa, South America, and the Caribbean. Giant salvinia was first reported to have escaped cultivation in South Carolina in 1995, and has since been reported in Texas, Louisiana, Mississippi, Alabama, Florida, North Carolina, Arizona, California, and Hawaii. Previous studies have reported that giant salvinia is dependent for growth on dissolved nutrients in the water and has optimal growth at circumneutral to slightly acid (pH of 6) water. We examined giant salvinia growth in a three-by-three factorial study of growth, with pH levels of 5, 6.5, and 8 and low, medium, and high concentrations of nutrients. Plants were grown in 378 L tanks, with each treatment replicated three times. At two-week intervals, two samples per tank were collected using a 0.01 m^2 quadrat and dried at 70°C. End-point analysis was performed using a two-way analysis of variance, with pH and nutrient level. Initial results after 35 days indicate that pH was not a significant factor in plant biomass ($p=0.65$), while nutrient level significantly affected growth ($p<0.001$). Although pH may not be a factor controlling giant salvinia growth, giant salvinia modifies water pH through decomposition of plant material and disruption of the water-air interface. Giant salvinia will likely succeed best in waters with high nutrient loading rates, and may not survive or compete in waters of low nutrient loading rates.

There Are No Hopeless Cases: Mitigating the Impact of Invasive Freshwater Fishes in The Cape Floristic Region, South Africa

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The exceptional level of endemism of the renowned flora of the Cape Floristic Region of South Africa is matched by the region's freshwater fish fauna (>80% endemism). There are currently 19 recognised primary freshwater fishes in the Cape Floristic Region (CFR), of which 16 are endemic to the region, 15 are listed as threatened, and 9 listed as endangered or critically endangered. Recent genetic and taxonomic studies have revealed greater diversity than previously recognised.

The indigenous fish fauna of the CFR is dominated (75%) by Cyprinids of the genus *Pseudobarbus, Barbus, Labeobarbus* and *Labeo*. Other endemic taxa found in the region include rock catfish (*Austroglanis*), an anabantid (*Sandelia capensis*), and the Gondwana relict *Galaxias zebratus*.) The indigenous fish of the region have evolved without piscivorous fishes that have now been introduced and are mostly small bodied and therefore very susceptible to predation

The major threats to these fishes are predation by, and competition from invasive alien fish and habitat degradation. Seventeen fish species have been introduced to the CFR from North America, Eurasia and elsewhere in southern Africa. Although the impact of most of these species is not fully understood, the most devastating impact has been from smallmouth bass (*Micropterus dolomieu*). Indigenous fish populations are now generally restricted to refuges above barriers in the upper reaches of rivers.

Case studies on two rivers where a barrier has limited smallmouth bass invasion has shown that smallmouth bass not only totally eliminate all minnow species, austroglanids, sandelia and galaxias, but also prevent recruitment of the larger bodied species e.g. Clanwilliam yellowfish (*Labeobarbus capensis*), and reduce the fish biomass to 10% of that of an indigenous fish assemblage. Further, the presence of smallmouth bass reduces predation pressure on aquatic invertebrates, increasing invertebrate grazing pressure on lower trophic levels.

A GEF-funded project has been initiated to remove alien fish from selected rivers in the CFR. An expert panel has prioritised six rivers for intervention and pre-intervention surveys are currently being undertaken. The planned intervention involves the use of the piscicide rotenone to remove the alien species. Careful planning is required to rescue populations of indigenous fish that currently occur with the alien species. This constitutes the first steps in the long walk to free our rivers of invasive alien species.

Nonindigenous Species of the Pacific Northwest: An Overlooked Risk?

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Nonindigenous species are recognized as one of the major threats to global diversity and have been cited as a cause of decline in 42% of species listed under the U.S. Endangered Species Act. During their life cycle, salmonids traverse large geographic areas spanning freshwater, estuary and ocean habitats where they encounter numerous non-native species. To date, the cumulative impact of nonindigenous species on salmonids has not been described or quantified. We examine the extent to which introduced species are a potentially important risk to threatened and endangered salmonids, ultimately by contributing to higher levels of life-cycle mortality. We identify and categorize all documented introduced species in the Pacific Northwest, including fish, invertebrates, birds, plants, amphibians and others. Where data exist, we quantify the impact of nonindigenous species on populations of threatened and endangered salmonids. For example, birds and fish predators are reported to consume 0-40% of juvenile salmon in some habitats. These data indicate that the impact of nonindigenous species on salmon is equal to or greater than commonly addressed impacts (habitat, harvest, hatcheries and hydro-system) and suggest that managing nonindigenous species impacts may be imperative for the recovery of these fish.

The Invasion of Giant Salvinia in the United States and its Suppression Using Classical Biological Control

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The floating fern, giant salvinia, *Salvinia molesta* D.S. Mitchell, can be one of the world's most invasive aquatic weeds. Native to southeast Brazil, it has spread around the world to Africa, India, Southeast Asia, Australasia, and the United States where it has formed thick mats in canals, lakes, rice paddies, and rivers. These mats disrupt or prevent activities like boating or fishing, block drains, spillways, and intakes for irrigation and electrical generation, provide harborages for disease-carrying insects like mosquitoes, crowd out native aquatic plant species, and reduce the oxygen content of the water which results in degraded fisheries. Its invasiveness was due to a lack of top-down regulation normally provided by natural enemies, especially invertebrate herbivores. Initially, the absence of natural enemies during its many invasions allowed rapid growth where, under optimum conditions, populations could double in size every 2-5 days and quickly cover the surface of slow moving bodies of water. Giant salvinia was first reported in the U.S. in 1995 from southeastern South Carolina, where it was eradicated within the year. In May 1998, plants were documented at a schoolyard pond in Houston, Texas and since then giant salvinia has been found at more than 90 sites, correlating to 41 freshwater drainage basins in 12 states. The worst areas were in Texas where three public reservoirs, five streams, and 20 ponds comprising 14 drainage basins were confirmed with giant salvinia. Our field research on the weed started in 1999 at sites in East Texas and Western Louisiana where fresh weight biomass readings exceeded 100 tons per acre at some sites with 100% coverage of virtually all bodies of water. We conducted the first release of the Brazil population of the biological control agent *Cyrtobagous salviniae* (Coleoptera: Curculionidae) in the U.S. in October 2001. Weevils have since survived four winters and have reduced the coverage and biomass of giant salvinia up to 99% at several release sites. We will present results of long-term studies on the population dynamics of giant salvinia and *C. salviniae* at multiple sites in Texas and Louisiana. At two sites, a nascent equilibrium is evident between insect and plant populations resulting in the maintenance of giant salvinia at greatly reduced densities. Currently, the weevils are spreading naturally and with some assistance from local agencies and will eventually provide suppression to a point where further chemical or mechanical control efforts will not be useful or advisable. We will discuss one instance of herbicide interference with biological control and how this could be avoided in the future. This project represents the best documented example of the efficacy of this natural enemy and provides guidance for its further deployment in the U.S.

Potential Biological Control of West Indian Marsh Grass (*Hymenachne amplexicaulis*) in Florida

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Invasions of exotic grasses constitute a major threat to aquatic ecosystems. West Indian Marsh Grass, *Hymenachne amplexicaulis* (Rudge) Nees, is currently invading the watersheds of central and south Florida, northern Australia and Indonesia. *H. amplexicaulis* is native to South America and the West Indies and has spread to most countries of the neo-tropics. *H. amplexicaulis* invades riverbanks, marshes and other areas subject to seasonal flooding. Reproduction involves the production of stolons and seeds that can be transported great distances downstream. Therefore, seasonal flooding associated with summer rainfall in Florida facilitates spread of this grass. Control measures of *H. amplexicaulis* rely on the use of registered herbicides. However, herbicides offer only a short-term control of *H. amplexicaulis*, as there is substantial regrowth from stolons and seeds after herbicide treatment. Therefore, more research is needed to find more effective measures to control this invasive grass in Florida.

Biological control has been a successful tactic to control invasive aquatic weeds worldwide. In Florida, a fortuitous insect was recently found causing severe damage to *H. amplexicaulis*. This insect was identified as *Ischnodemus variegatus* (Hemiptera: Blissidae) and it is consider native to South America. However, little information is known about the biology and ecology of this herbivore, and its potential to control *H. amplexicaulis* in Florida. Therefore, the host range of this herbivore and its potential to control *H. amplexicaulis* were evaluated under laboratory and greenhouse conditions. Host range test included taxonomically related species, grasses grown as food crops, turf grasses used in Florida, and grasses with ecological similarities to the target plant. So far, we have tested 60 plants under non-choice conditions for development and five plants for oviposition. Results showed that *I. variegatus* can develop from nymph to adult on *H. amplexicaulis, Panicum hemitomon, Panicum anceps* and *Thalia geniculata*. However, oviposition non-choice tests demonstrated that *I. variegatus* females only lay eggs on *H. amplexicaulis*. A factorial experiment containing different levels of nutrient, water level and insects was performed under greenhouse conditions. No interaction was detected between water level and insect density for all variables analyzed. High infestations (10 insects/plant) of *I. variegatus* were capable of reducing the growth rate, chlorophyll levels and biomass of *H. amplexicaulis* seedlings. Early damage of *I. variegatus* on seedlings of *H. amplexicaulis* is characterized by brown rounded necrotic spots on the leaf and if the infestation continues the plant turns brown and dies. The major damage to the grass occurs by withdrawal of fluids from phloem and the stoppage of vascular tissues by sheath material left by the mouth parts.

Field sampling of natural infestations conducted in the Myakka River State Park showed that *I. variegatus* increase from May to October reaching up to 30 insects per stem. Despite the high densities of *I. variegatus*, only a small decrease of chlorophyll content and panicle length was detected in full-grown *H. amplexicaulis* stands. Ongoing studies are conducted to assess the effect of early infestations of *I. variegatus* on *H. amplexicaulis* under field conditions.

The Impacts and Management of Torpedograss (*Panicum repens*) in the Marsh of Lake Okeechobee, Florida

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Lake Okeechobee is Florida's largest lake, spanning 466,000 acres of which emergent marsh covers approximately 100,000 acres. The shallow, main body of the lake is eutrophic; however, the oligotrophic marsh is functionally separated from the main portions of the lake. The marsh water is primarily derived from rainfall and has historically supported a diverse low-density native plant community. The marsh system serves as critical habitat for Federally-endangered wildlife including the Everglades snail kite (*Rostrhamus sociabilis*) and the Florida-endemic Okeechobee gourd (*Cucurbita okeechobensis*). Numerous other species including resident and migratory waterfowl, marine and freshwater mammals and a diverse fishery inhabit the lake and the marsh. The lake also supports commercial and sport fisheries valued at millions of dollars annually.

Lake Okeechobee borders the sub-tropics and has been subject to numerous non-native plant and animal invasions. One of the most threatening has been torpedograss (*Panicum repens* L.), a Eurasian species which had, by 1996, invaded 20,000 acres of the lake's marsh. Torpedograss shares many successful competitive advantages with other invasive species including wide environmental tolerances, rapid plant growth rates, low nutrient requirements and freedom from pests found in its native range. In Florida, its growth quickly establishes dense monocultures, which persist through fire, drought and flood and overwhelm existing native plant communities. Resultant shoot densities effectively prevent aquatic wildlife ingress and egress into infested areas.

Management efforts have proceeded for five years and been modified with gained experience and the availability of new materials and methods. To date, single treatments with herbicides have gained multi-year control over thousands of acres and yielded rapid re-appearances of numerous native species. Also, winter-time treatments have allowed selective control of torpedograss without significant damage to winter-senescent species such as buttonbush (*Cephalanthus occidentalis*). Management efforts must continue to investigate whether best management techniques are being used while expanding control to prevent further losses to floral and faunal communities and adverse economic impacts to the region.

New Herbicidal Tools for Integrated Management of Aquatic Invasive Plants

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As freshwater resources continue to be strained by anthropogenic pressures, effective management of aquatic invasive plants increasingly demands improvements in methods for control of these problem species. Unfortunately, few tools are available to integrate into effective management strategies for aquatic invasive plants. This limited number of technologies, specifically chemical or biological in nature, increases the risk of problems such as herbicide resistance, reduced selectivity of treatments, or other undesirable effects associated with repeated use of the same methods. It is recognized that the most effective means to control many invasive species is through integration of multiple techniques, which unfortunately are in short supply for most aquatic plant problems. Two new technologies for aquatic plant control are under development as potential new tools for aquatic resource management. Penoxsulam is an acetolactate synthase inhibitor newly registered by USEPA as a Reduced-Risk herbicide for rice agriculture. Recent work has shown that penoxsulam has excellent activity on a number of highly invasive aquatic weed species including hydrilla (*Hydrilla verticillata*), water hyacinth (*Eichhornia crassipes*), and giant salvinia (*Salvinia molesta*). The chemistry can be used either through in-water application or via foliar sprays to provide effective control of these species with good selectivity. The slow mode-of-action of the chemistry allows large infestations of these weeds to be treated with minimal risk of water quality impacts such as dissolved oxygen declines due to vegetation decay. In-water field trials on over 160 ha in 2005 documented simultaneous control of multiple problem weeds including hydrilla, hyacinth, and water lettuce (*Pistia stratoides*) with extensive quantification of efficacy, selectivity, and dissipation through hydro-acoustic survey, hyper-spectral imaging, and other forms of geo-referenced field assessment. A mycoherbicidal biological agent, *Mycoleptodiscus terrestris* (Mt), is another technology under development for selective control of submersed invasive plants including hydrilla, Eurasian watermilfoil (*Myriophyllum spicatum*), and Brazilian waterweed (*Egeria densa*). Isolated from infected hydrilla in Texas, the Mt strain under development has been cultured with improved, patented fermentation methods that increase stability and infectivity of the fungus. Additional formulation modifications designed to improve underwater adherence to target submersed species have increased virulence on hydrilla. Integrative studies with other aquatic herbicides have shown excellent promise in increasing Mt efficacy while decreasing application rates of both the biological and chemical control agents.

Effectiveness of Product LSP® in the Growth Inhibition of the Duckweed (*Lemna* sp.) of Maracaibo Lake, Venezuela

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LSP® is an mixture of controlled strong and weak acids, with pH<1. Bioassays were conducted using water of the Lake of Maracaibo (Venezuela) to evaluate the effectiveness of LSP®, in the growth inhibition of the aquatic plant *Lemna* sp (Duckweed) and its toxicity on Fish Larvae "Alevins" and on white shrimp larvae PL10 (*Litopeneaus vannamei*). Results showed the fast growth inhibition of the *Lemna* sp by Chlorosis. The 96LC50 Toxicity assays established the following results: 100% of Alevins and 84% of the Shrimp larvae survived after 96 ho exposure to LSP®. Another low pH compound, 4B™ was diluted with water in the range of concentrations 1:10 to 1: 3500 to evaluate efficacy in the inhibition of the growth of the invasive sub aquatic plant Elodea (*Hydrilla verticillata*). In vitro results show inhibition of growth and death by exposure, before the 24 hour period, of aerobic and anaerobic microorganisms contained in the water samples taken from the bottom of the culture pond. In vivo results also show death of the plant before the 24 hour period after exposure to4B™. Elimination of CO_2 caused by 4B® is fundamental to block the photosynthesis process in Elodea (*Hydrilla verticillata*).

Investigation on the Status and Impact of Jaguar Guapote in Taal Lake, Philippines

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The survey was undertaken from March to June 2005 in Taal Lake to determine the abundance, distribution and impact of a newly discovered alien species, and the results may serve as a basis in formulating management measures to prevent further invasion and to conserve the endemic and indigenous fish species in the lake. Taal Lake is the third largest lake in the Philippines and habitat of the only freshwater sardine *Sardinella tawilis*, giant trevally *Caranx ignobilis* and other commercially important indigenous species.

Morphological characteristics of the alien species showed that it belongs to Family Cichclidae *Parachromis managuensis* known as Jaguar guapote and has invaded the northeastern portion of Taal Lake covering Tanauan, Talisay and Laurel. Talisay area has the highest catch of guapote sharing 75-88% of the total catch of gill net. On the other hand, Tanauan and Laurel area shared only 15-20.0% of the total catch of fish corrals, and 5-13.0% of the total catch of gill net, respectively.

Juvenile to mature samples were noted in Talisay and Tanauan area which may indicate that guapote has already proliferated. Major food items observed were partly digested fish and fish scales (Cichlids), which showed that guapote is highly piscivorous species. Guapote is already accepted as food in the locality, but based on interview and gross sales of the fishermen particularly in Talisay area, their income has decreased. Endemic and indigenous fish species caught in the area commands much higher market value compared to guapote.

The IR-4 Project: New Opportunity – Aquatic Herbicide Registration

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The IR-4 Project is a publicly funded effort to support the registration of pest control products on minor or specialty crops. Its historic mission has been to provide pest management solutions to the growers of vegetables, fruits, ornamentals and herbs. The IR-4 Program develops data for submission to the U.S. Environmental Protection Agency (USEPA) to support the regulatory clearance of new crop protection chemicals on specialty crops and assists in the maintenance of existing product registrations. The IR-4 also provides aid in the development and registration of bio-pesticides and expedites new pest control technology, such as seed technology and methyl bromide alternatives. Concerned about increasing invasive aquatic weed problems, experts from the U.S. Environmental Protection Agency (USEPA), the U.S. Department of Agriculture, the U.S. Army Corps of Engineers, land grant universities, scientific groups and IR-4 joined together to form the Aquatic Herbicide Working Group. A white paper entitled "New Missions for the IR-4 Project-Weed Control in Aquatic Sites and Irrigation Canals" was completed and approved by the IR-4 Project Management Committee. Stakeholder support for the concept was obtained in February 2005 at IR-4 Strategic Planning Conference. If resources are made available from sources outside current program funding, IR-4 will work with stakeholders to obtain registration of herbicides for use in irrigation canals and water bodies that supply irrigation water for production agriculture.

Invasion at a Snail's Pace: *Pomacea canaliculata* and Everglades National Park

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A nonindigenous apple snail in the *Pomacea* "*canaliculata* group", an introduced species from South America, was collected within Everglades National Park (ENP). The snail poses a threat to ENP marshes because of its rapid, non-selective consumption of aquatic plants and high reproductive rates. Another concern surrounds the exotic snails' potential affects upon the native Florida apple snail, *Pomacea paludosa*, a major prey item for the endangered Snail Kite, *R. s. plumbeus*, and various fauna within ENP. As a macrophytic herbivore, it has harmed the rice industry in Southeast Asia for several years causing substantial economic loss and it alters wetland function in ecosystems where introduced. This invasive aquatic invertebrate has been previously reported in northern portions of Florida, and has slowly increased its range to include southern Florida.

Initial observations of the snail occurred during May 2005 along the northern park boundary in the Old Tamiami canal adjacent to the Shark Valley portion of ENP. After initial observation, ENP staff began efforts to assess current population and distributions of the invasive snails near the northern park boundary in the Old Tamiami canal using transect survey methods. Assessment was conducted by actively looking for egg masses, adult snails, and empty shells to indicate snail presence. Prior to wet season flooding, the highly visible egg clusters were found primarily on woody vegetation along the canal bank. After flooding events in June fewer egg masses were found near the canal banks, but egg masses and adults were located in marshes adjacent to the canal. *P. Canaliculata* is predominantly found in canal habitats in Florida, therefore its colonization in marsh habitats seems to be unique to ENP. Initial control efforts conducted by park staff included transect work using hand removal of adults and egg masses as well as some trapping of adult snails along the Old Tamiami Canal. As water levels rose, hand removal and active search techniques were conducted in the canal's associated marshes. Surveys and removal efforts were also conducted by park and South Florida Water Management District staff in the L-29 canal which connects to the Old Tamiami canal via water control structures.

When considering the impact of *P. canaliculata* on similar ecosystems, this invasive snail is considered to be a significant threat to Everglades' wetlands. Park staff are currently continuing to document the snail's distribution in ENP as well as researching opportunities to control, reduce, or eliminate the invasive snail to end its dispersal into ENP. The discovery of this newly introduced species within ENP reemphasizes the need to develop rapid response protocols and management policies to address future invasive species. Although the effects of the channeled apple snail in the Everglades marshes remain unknown an increase in the abundance, proportion, or number of species of exotics indicates adverse conditions for the restoration of Everglades National Park.

Use of Long-term Monitoring Data to Evaluate Potential Impacts of Asian Carp on Native Filter-feeding Fishes in the Upper Mississippi River System

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Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*H. molitrix*) were accidentally introduced into the Mississippi River system in the 1980s, presumably from the aquaculture industry. Both *Hypophthalmichthys* spp. are filter feeders and it has been suggested that they could potentially impact native filter-feeders because of similar dietary preferences. We used 10 years of daytime electrofishing data collected by the Long Term Resource Monitoring Program (LTRMP) in three Asian Carp colonized reaches of the Upper Mississippi River System (UMRS; Pool 26, unimpounded UMR, and LaGrange reach of the Illinois River) and one un-colonized reach (e.g., control site) of the UMRS (Pool 13) to test for potential impacts from *Hypophthalmichthys* spp. on annual Gizzard Shad (*Dorosoma cepedianum*) and Bigmouth Buffalo (*Ictiobus cyprinellus*) biomass estimates. Although we found negative, but non-significant correlations for stock and sub-stock *D. cepedianum* in the colonized reaches (except Pool 26 for stock), before-and-after impact (BACI) analyses revealed no significant interactions among biomass estimates from the colonized and control sites before and after Asian Carp establishment. The only negative, yet non-significant correlation for *I. cyprinellus* biomass was for sub-stock in the LaGrange Pool, and BACI revealed no significant interaction among biomass estimates this reach and the control reach before and after Asian Carp establishment. Although we found no significant correlations or interactions in our analyses, we can not confidently conclude that there are no negative impacts from Asian Carp on native filter-feeding fishes because the UMRS is a highly productive system and resources may not yet be limited. Conversely, impacts may not yet be identifiable because of the short time-series since Asian Carp establishment in the UMRS. Despite not identifying significant BACI results for *D. cepedianum* and *I. cyprinellus*, we recommend continued monitoring of these species because we did identify negative correlations in biomass through time for at least one of the *Hypophthalmichthys* spp. colonized sites.

Bozeman Fish Technology Center – Aquatic Nuisance Species and Aquatic Animal Health Program

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The U.S. Fish and Wildlife Service (USFWS)-Bozeman Fish Technology Center (BFTC) added a new program to the facility in April 2005. The Aquatic Nuisance Species (ANS) and Aquatic Animal Health Program mission is to increase knowledge of aquatic nuisance species threats to aquatic systems and promote aquatic health through research, outreach and technical assistance. There are five main goals of this program: 1) Improve ANS detection and identification of colonization pathways, 2) Acquire biological and ecological information on ANS and important indicators of aquatic system health, 3) Determine effects to natural ecosystems, threatened and endangered species and industry 4) Disseminate information through education, outreach and technical assistance, and 5) Survey National Fish Hatchery water supplies and effluent systems to identify ANS and potential hazards. The BFTC has been working together with State and Federal agencies on a regional and national level to support the mission and goals of this program.

A Potential Role for Alien Sunbleak *Leucaspius delineatus* in the Further Dissemination of a Non-native Parasite

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Social network analysis indicated that during early life social groups is stronger between sunbleak *Leucaspius delineatus*, an invasive fish species, and the native species than between the natives themselves. This is an important factor as it relates to the speed with which information such as disease can spread within a community. The study of the parasites of sunbleak also revealed that it is a host for two non-native copepodid parasites, *Neoergasilus japonicus* and *Ergasilus briani*, which are of Asian and Eurasian origin, respectively. While *E. briani* has previously been reported in sunbleak within its native range, this is the first record of *N. japonicus*. The distribution of *N. japonicus* in England is limited to few locations but with the rapid dispersal of sunbleak there is concern that *N. japonicus* may be dispersed to new areas in England as well as the whole of the UK. Our study confirms that alien fish species represent not only a great risk of exotic disease introduction but may also be successful vectors for their dissemination, as has been demonstrated by their high degree of socialisation with native species.

Impact of Invasive Grasses on Crop Production in Guyana

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Guyana lies between latitudes 1 and 10º north of the equator and longitudes 57 and 61º west from Greenwich on the northeast coast of South America. The population is concentrated along the coast, which is below sea level at high tide. Agricultural activity along the coast accounts for about 31% of gross domestic product (GDP). The largest single item in development budgets since the 1960s has been 'drainage and irrigation'. The introduction of invasive grasses, *Echinochloa pyrimidalis* and *Brachiaria radicans* has resulted in rapid infestation of drainage and irrigation canals throughout the coast and a steady increase in the cost of maintaining the systems. This negative impact came at a time when the two major industries, sugar and rice, are battling to reduce the cost of production and increase their chances of survival.

Both grasses are aggressive and can block both the internal and external drainage systems in sugar, rice and other crops. They can also interfere with crops by competition and allelopathy. Flooding in two riverine rice growing areas were recently attributed to the presence on *E. pyrimidalis* in the rivers. The rapid spread of these grasses can therefore change the landscape permanently and the livelihood of farmers.

Mytella charruana Along the Atlantic Coast of Florida: A Successful Invasion?

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Biological invasions are now recognized as one of the most serious problems confronting the integrity of native species and ecosystems around the world. Unfortunately, invaders often go unnoticed until they have spread extensively, making eradication difficult and very costly. Early detection and rapid response to such invasions are vital to prevent potential evolutionary and ecological changes that could damage both our ecosystems and our economy. *Mytella charruana*, a tropical mussel native to Mexico and South America, first appeared in large numbers in the seawater intake pipes of a Jacksonville, Florida power plant in 1986. Fortunately, they never became established as the founder population was extirpated the winter of 1987, presumably due to cold temperatures. No new sightings of this species were recorded until 2004. Then, a population of *M. charruana* was discovered in Mosquito Lagoon, Florida (170 km south of Jacksonville) in August 2004. Since then the area has been surveyed monthly for mussel occurrences. Specimens were found August 2004-February 2005 on manmade debris, driftwood and living oysters. No individuals were found again until August 2005. Environmental parameters (salinity, water depth, water and air temperature) were recorded during surveys. If ecological conditions are optimal for continued survival and establishment of *M. charruana*, this species has the potential to reproduce and out-compete native mussels and declining oyster populations of the area. Our goal is to better understand this invasive species before this happens. Rapid actions are needed to prevent *M. charruana* from having the economic and ecological impacts of the zebra mussel *Dreissena polymorpha* and green mussel *Perna viridis*.

Managing Natural Resource Pathways with HACCP: Planning is Everything

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In natural resource work, equipment and organisms are often moved from one location to another. The specific equipment or organism being moved is called the target. Targets could include animals for relocation or stocking for recreation, equipment such as a bulldozers and backhoes, sampling gear such as nets or traps, and even people. Transporting targets provides a potential vector for the spread of non-target species that could potentially invade new habitat. Non-target species are the plants, animals, diseases, pathogens and parasites that are not intended to be moved. As Natural Resource Managers, it is essential that we do our best to remove these hazards from pathways.

Resource management work often creates open pathways that could spread invasive species to unique and critical habitats for already endangered species. Next to habitat loss, invasive species are resource management's biggest challenge. Executive Order 13112, 1998, directs agencies to prevent the spread of invasive species in their work but few management tools exist to implement this Directive. Hazard Analysis and Critical Control Points (HACCP) planning has been modified from the food industry for natural resource work. Around the world industry uses the HACCP planning tool to remove product contamination. In natural resource pathways, hitchhiking species are considered contaminants. HACCP's comprehensive planning identifies these species and the risk of contamination while documenting the best management practices used to prevent and remove hitchhikers.

HACCP planning focuses attention on critical control points where non-target species can be removed. Documenting risks and methods used to remove non target species gives managers a strategic method to make consistent decisions based on identified risks. Planning builds a logical framework of information to weigh risks for species spread against management benefits.

Why? A few errors can have long-lasting affects on agency mission! Additional planning support is available on this web site where a planning manual, supporting documents, forms and a database of completed HACCP plans are available in several formats.

Where Did They Come From and Where Are They Going? Genetic Analysis of Sources and Sinks for the Round Goby and Zebra Mussel

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A series of invasions have altered the ecosystems of the Laurentian Great Lakes over the last two decades. Among these, the round goby [*Apollonia (Neogobius) melanostomus*] and the zebra mussel (*Dreissena polymorpha*) have a coevolved predator-prey relationship that survived their translocation from their native Ponto-Caspian region. Both are highly successful invaders, whose populations have expanded rapidly. Using mitochondrial cytochrome b sequences, we compare and contrast the genetic structures of these potentially linked invasions. The project's goals are to identify patterns of genetic diversity, gene flow, and divergence in order to evaluate possible connections among invasive sites and with their putative Eurasian donor regions. Results show that invasive round gobies in North America display considerable genetic divergence among sites, supporting the hypothesis of multiple founding sources and differential colonization patterns. Zebra mussels have somewhat higher levels of gene flow between North American sites, and less pronounced population structure. Nuclear DNA patterns showed greater site specificity than was found with mtDNA. Genetic composition of the zebra mussel population in the Hudson River significantly changed over a decade, indicating immigration and extinction of genotypes. Moreover, invasive populations of both zebra mussels and round gobies possess genetic diversity levels comparable to those found in native Eurasian sites, showing no founder effects. High levels of genetic diversity render both species highly adaptable to novel environments, likely increasing their invasive success. Genetic data sets thus are useful for identifying founding sources, as well as patterns of spread and new colonizations. Genetic studies may allow agencies to concentrate control efforts on the most virulent donor locations in order to minimize further introductions.

A Method for Distinguishing Dark False Mussels from Zebra Mussels

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In recent years, the introduction, establishment and dispersal of zebra mussels (*Dreissena polymorpha*) and quagga mussels (*D. bugensis*) [Family Dreissenidae] throughout much of North America has had considerable consequences – both economic and ecological. As a result, considerable effort and expense has been put into monitoring programs, by both the public and private sectors, for the early detection of these invasive mussels. Most aquatic invasive species – such as the rusty crayfish (*Orconectes rusticus*), the veined rapa whelk (*Rapana venosa*), and the Chinese mitten crab (*Eriocheir sinensis*) – are conspicuous and easily identified. And, even the external morphology of juvenile and adult zebra mussels and quagga mussels, which are congenerics, is so dissimilar that they are rarely misidentified.

However, there has been considerable confusion in the identification of juvenile and adult zebra mussels and the dark false mussel, *Mytilopsis leucophaeata*, a related species which is endemic to portions of the eastern United States, as there is similarity in external morphology and overlap in habitat requirements. The optimal salinity tolerances for zebra mussels (0.0-1.5 ppt) and dark false mussels (5.0-8.0 ppt) are such that populations are generally allopatric, that is, spatially segregated. However, the range of salinities in which zebra mussels (0.0-4.0 ppt) and dark false mussels (0.2-18.1 ppt) can normally be found is such that sympatric populations can occur, with overlapping distributions.

Despite such similarities, a careful comparison of internal anatomical features of juvenile and adult zebra mussels and dark false mussels is sufficient to readily differentiate these species. Most conspicuously, the "beak" of zebra mussel shells has a broad myophore shelf and no underlying apophysis while the beak of dark false mussel shells has a narrow myophore shelf and a distinct underlying apophysis. These characteristics alone – despite several other anatomical dissimilarities – are generally sufficient to distinguish one species from the other. This poster is intended to provide a simple method for distinguishing dark false mussels from zebra mussels.

Navigational Buoy Survey of Invasive and Native Benthic Invertebrates of the Lower Great Lakes and St. Lawrence River

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In January 2005 and January 2006 we examined navigational buoys for invasive and native benthic invertebrates that had colonized these substrates in the St. Lawrence River and lower Laurentian Great Lakes throughout the 2004 and 2005 shipping seasons. This report details our fifteenth and sixteenth years of a long-term monitoring program.

The buoys are removed from the water every December when winter navigation is closed due to icy conditions, then replaced in the same location every March. Since the invasive dreissenid mussels peaked in the mid 1990s, we have expanded our survey from the upper St. Lawrence and Eastern Basin of Lake Ontario, to Lake Erie and Lake St. Clair to the west, and eastward toward Montreal. Our survey in 2005-2006 concentrated on dreissenids as well as the invasive amphipod crustacean, *Echinogammarus ischnus*. We have also documented the presence of the invasive gastropod, *Bithynia tentaculata*, but note that this benthic snail does not readily colonize the buoys. Also, we have examined the populations of native caddisflies (locally known as shadflies), and native amphipod crustaceans to determine whether they are experiencing changes in distribution and abundance correlated with those of molluscan and crustacean invaders. We examined nearly 300 buoys in 2005 and 2006 in Canadian and U.S. ports and navigable waterways.

Dreissenid mussel populations are remaining relatively stable, with wide differences between sites. Dominance of *Dreissena polymorpha* in major Lake Ontario ports such as Kingston and Toronto, and dominance of *Dreissena bugensis* in the most of the upper St. Lawrence River, remain similar to patterns in recent years. Overall, dreissenid abundance increased in the river in 2005 relative to 2003 and 2004. Abundance and distribution of hydropsychid caddisflies, remain stable in the area near Cornwall, Ontario and Massena, New York, where they are the dominant benthic macroinvertebrate. In contrast, the important population of *Brachycentrus incanus* caddisflies downstream from Prescott, Ontario and Ogdensburg, New York reached an all-time low in 2005-2006, and were scarcely detectable on buoys even though they were the dominant benthic macroinvertebrate in that stretch of the river prior to the dreissenid invasion. Amphipods remain more abundant than caddisflies on buoys from the upper parts of the river and Lake Ontario, but we have not yet determined relative abundance of native and introduced amphipod species.

We plan to continue this annual survey into the foreseeable future to develop a long-term perspective of these important changes. This will continue to provide baseline biotic data for the St. Lawrence River and lower Great Lakes, and establishes a model for similar studies on other major river systems.

Fatty Acid Composition of the Invasive Caprellid, *Caprella mutica* (Crustacea: Amphipoda) on the West Coast of Scotland: Trophic and Environmental Implications

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The introduction of non-native species is one of the most pervasive, irreversible and devastating impacts of human activity on natural ecosystems. The frequency and distribution of biological invasions is ever-increasing, and it is important to understand the consequences of these invasions on marine ecosystems. One of the effects of the introduction of non-native species can be the displacement of native plants and/or animals as a result of competition for food. Successful invasive species typically exhibit a generalist feeding strategy, consuming a wide variety of diet types.

Caprella mutica, a non-native epifaunal amphipod, which originates from sub-boreal areas of northeast Asia, was first identified in the UK on the west coast of Scotland in 2002. This species typically inhabits artificial structures, including aquaculture infrastructure, marina pontoons and boat hulls at extremely high densities at certain times of year (> 60,000 m^{-2}). The feeding strategy of *C. mutica* is unknown. Previous studies have found that diet type can influence the fatty acid composition of herbivorous crustaceans, including the Caprellidae and that certain fatty acids, or their ratios, can be used to provide a more precise indication of an organism's diet than analysis of the gut contents.

The aims of this study were to investigate the fatty acid profiles of *C. mutica* to determine whether this species had a generalist feeding strategy. Replicate samples were collected from sites exposed to different levels and composition of particulate organic material (i) fish farm, (ii) mussel farm and (iii) mooring lines > 2 km from mariculture activity. The fatty acid profiles were determined for these samples and compared to *C. mutica* either fed (i) the microalgae, *Dunaliella tertiolecta*, (ii) the diatom, *Phaeodactylum tricornutum* or (iii) no additional feed for 21 days in the laboratory.

The results showed that *C. mutica* contained high levels of polyunsaturated fatty acids, particularly eicosapentaenoic acid, 20:5 (n-3); other major fatty acids were palmitic acid, 16:0 and oleic acid, 18:1 (n-9). Significant differences in the fatty acid profiles between caprellids fed on the microalgae and diatom diets and between animals collected from the field sites were observed. The results indicate that *C. mutica* does have a highly generalistic feeding strategy and the implications of this strategy in relation to competition with native epifaunal species for food will be discussed.

Don't Release Aquatic Invasive Species Into the San Francisco Bay/Sacramento-San Joaquin River Delta: A RIDNIS Project Outreach Poster

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The San Francisco Bay-Delta is the most invaded aquatic ecosystem in North America with over 250 introduced species. Developing and delivering clear educational messages about aquatic invasive species (AIS) to target audiences can help prevent their spread. One of the goals of the RIDNIS Project (Reducing the Introduction and Distribution of Non-native Aquatic Invasive Species through Outreach and Education) was to produce a colorful illustrated poster in English and Chinese (Mandarin) about preventing the spread of AIS. The water-resistant 18" x 24" poster focuses on non-ballast water pathways by which these species can be released (live bait and seafood, recreational boating and angling, and aquarium and water gardening hobbies). The poster illustrates these pathways and suggests ways in which people of all ages and cultures can help reduce the number of new invasions in the Bay-Delta. AIS depicted in the poster include: European green crab (*Carcinus maenas*); Caulerpa (*Caulerpa taxifolia*); zebra mussel (*Dreissena polymorpha*); water hyacinth (*Eichhornia crassipes*); Chinese mitten crab (*Eriocheir sinensis*); and New Zealand mudsnail (*Potamopyrgus antipodarum*).

Development of DNA-based Tools for Identification and Monitoring of Aquatic Introduced Species

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Claims for potential applications of DNA taxonomy range from identification of unknown specimens and the discovery of new species to the study of biodiversity through comprehensive characterizations of complex biotic communities drawn from environmental samples. Recently, these applications have been widely recommended for the identification and monitoring of introduced and invasive species. DNA-based approaches have the capacity to provide rapid, inexpensive, and technically accessible tools for managers tasked with recognizing and preventing the importation and/or spread of potential invasives. Some recent studies have demonstrated the feasibility of such tools, at least for the most straightforward applications. However, significant technological hurdles must be overcome before more ambitious applications are realized. Here we explore the promise of a number of DNA-based tools for various applications associated with the identification and monitoring of aquatic invasive species, and review potential limitations in their application and technical difficulties associated with their development. By categorizing these tools based on characteristics of target samples and the desired outcomes of each application, we provide a conceptual framework for assessing the appropriateness of particular tools for solving particular problems. We also summarize some recent empirical data illustrating the promise of DNA-based applications, along with the challenges involved in their development. Specifically, we review the design of targeted PCR approaches to screening for green crab (*Carcinus maenas*) and mitten crab (*Eriocheir sinensis*) larvae in ballast water, and describe attempts to characterize complex ballast water communities based on the determination of DNA "barcode" sequences (mitochondrial cytochrome C oxidase subunit I, COI). Green crab- and mitten crab-specific PCR primers have been developed based on comparison of COI sequence from these target species and other brachyurans, and by testing green and mitten crab microsatellite loci for cross-amplification with the congeners and other closely related species. We explore the specificity and sensitivity of these primers by screening both control communities of known composition and ballast samples collected from a number of U.S. west coast ports. We also present results of ballast community characterization based on shotgun cloning and sequencing of COI fragments generated by universal PCR of bulk-extracted DNA. These results clearly demonstrate that such approaches are seriously constrained by biases in PCR and/or DNA extraction efficiencies, and by the limitations of available sequence databases.

Chinese Mitten Crab (*Eriocheir sinensis*) in the St. Lawrence River (Canada): New Records and Risk of Invasion

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Following the first report of the Chinese mitten crab (*Eriocheir sinensis*) in the St. Lawrence River in September 2004, we present here information of additional sightings made in 2004 and 2005. To date, healthy immature specimens were captured in commercial fishing gears at various locations in the freshwater section of the St. Lawrence River, between Quebec City and Montreal. The new occurrence of this exotic species coincides with an increase in maritime traffic in the St. Lawrence Seaway in recent years. Sites of capture were between 65 and 180 km upstream of the St. Lawrence estuary, where saline waters are optimal for reproduction and larval development. Potential risk of invasion in the St. Lawrence River basin and along the east coast of North America is discussed.

The Limnological Characteristics of Aquatic Environments Which Support the Golden Mussel (*Limnoperna Fortunei*, Dunker, 1857) and the Potential of the Golden Mussel to Further Spread Within the Paraguay River Basin, Brazil

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The bivalve *Limnoperna fortunei* (Dunker, 1857), also called golden mussel, is a native of the Southeast of China. Introduced into South America in 1991 by ballast water, it quickly spread into the Parana and Paraguay River basins. This species has successfully colonized approximately 2100 km of Paraguay River including the Pantanal floodplain. The commercial navigation in the Paraguay-Parana waterway is the main cause of *L. fortunei* introduction to upstream areas. Local navigation is important in the lateral dispersal of the species into the lakes of the floodplain. The purpose of this study was to describe the limnological characteristics of the high Paraguay River basin where *L. fortunei* is plentiful and analyze further potential for spread in it. From literature we know that *L. fortunei* has been found mostly in waters where dissolved oxygen is higher than 1.0 mg/L, pH is higher than 6.4 and calcium concentration is above 3.0 mg/L. In our study we analyzed the water temperature, dissolved oxygen, pH, Chlorophyll-*a*, suspended solids and calcium concentration at thirty-three locations in the Paraguay River basin. We found *L. fortunei* in low densities at locations where oxygen concentrations were essentially anoxic (~ 0.0 mg/L) and pH was 5.5. These conditions were observed during the beginning of the annual flood cycle in this region. The low oxygen and low pH are the result between the river and the floodplain contact and may last weeks or months depending on the year. The calcium concentration in Paraguay River and floodplain oscillates from 1.5 to 24.2 mg/L increasing from the north to the south. The water temperature in this region ranges from 10 to 34.5°C and the lowest temperature was 16°C in winter. The role, which suspended solids play in the survival of *L. fortunei*, is not clear. In the Upland Rivers, suspended solids were about 290 mg/L while in the floodplain area its was between 1.0 and 114.0 mg/L. The chlorophyll-*a* was low about 2.0 µg/L. The long-term survival of *L. fortunei* under these extreme conditions is uncertain and will be subject of our upcoming study. It may well be that if these conditions persist for months as they do in some years, *L. fortunei* will be eliminated from this area. Of course due to shipping, re-introduction of the species is certain once conditions return to normal. Although *L. fortunei* has access to a number of the tributaries of the Paraguay River, to-date it was observed only Miranda and Apa Rivers. In these rivers the lowest pH was 7.4, the calcium concentration was more than 12.6 mg/L and the oxygen was above 2.0 mg/L. In some of other rivers where *L. fortunei* was not yet observed the lowest concentration of oxygen varied from 0.9 to 2.1 mg/L increasing from the floodplain to the highland areas, most pH values were below 6.3 and the lowest calcium concentration was about 2.3 mg/L. Although it may be introduced into these rivers, *L. fortunei* will not probably survive or may eventually be found in low densities.

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Dispersal, Recruitment and Survival of the Exotic Brazilian Pepper in a Florida Estuary

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Brazilian pepper, *Schinus terebinthifolius*, has invaded most central and south Florida ecosystems, competing with native flora and often resulting in monotypic stands of this exotic species. Past research has questioned its ability to successfully invade estuarine systems with saturated, saline soil conditions. However, field observations of the shoreline of Mosquito Lagoon (Canaveral National Seashore, New Smyrna Beach, FL) found Brazilian pepper growing alongside three native species of mangroves, *Rhizophora mangle*, *Laguncularia racemosa* and *Avicennia germinans*. The purpose of this study is to examine the ability of Brazilian pepper to: 1) invade coastal habitats by dispersing seeds in the water and 2) tolerate conditions within the mangrove canopy. The potential for water dispersal was determined by measuring the length of time seeds remain buoyant, the distance seeds traveled within Mosquito Lagoon and the viability of seeds after soaking in saltwater for up to fourteen days. Results from these experiments were used to determine if water dispersal was a viable, secondary vector for seed dispersal. The tolerance of Brazilian pepper to mangrove canopy conditions was determined by growing Brazilian pepper under various combinations of light (0, 30% and 70% shade), salinity (0, 15, and 30 ppt) and soil moisture (0, 50% and 100%) treatments. In addition, field monitoring of the recruitment and survival of Brazilian pepper and native flora in mangrove systems occurred monthly for one year at five sites in Mosquito Lagoon. Results from the lab trials and field monitoring were used to determine limiting factors of the estuarine system, which may prevent the establishment of Brazilian pepper. These experiments lead to a better understanding of the ecological limits of Brazilian pepper when present in Florida estuarine systems and can assist coastal research managers with the control and eradication of this exotic species.

The National Park Service Exotic Plant Management Teams (EPMTs) Free Standing Display

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The National Park Service Exotic Plant Management Teams (EPMTs) were created in 2000 as a new resource management tool, modeled after the approach to fight wildfires. The 16 NPS EPMTs are serving over 209 parks controlling harmful invasive species that threaten natural and cultural resources. EPMTs have identified, treated or monitored over 17 000 acres and eradicated six species of exotic plants from parklands. EPMTs are also building capacity to meet the growing demand for information and technical resources to manage exotic plants. Other land management agencies are now considering adoption of the NPS model. This free standing professionally developed display describes program design, implementation, contracting, partnerships and new technical capabilities such as the Alien Control Plant Management Database (APCAM).

Bioinvasions in Nearshore Restoration Projects: How Can Policy and Management of Invasions Be Most Effective?

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Nonindigenous species have invaded many ecosystems throughout the world, often causing negative impacts to native species, native habitats, and natural ecosystem processes. Invasive species are known to capitalize on disturbed ecosystems, sometimes surviving in conditions not suitable for native species. Disturbance associated with ecosystem restoration activities can increase the vulnerability of restoration sites to invasion by nonindigenous species. However, much of invasive species management in restoration programs is created and carried out on an *ad hoc* basis; as problems occur, management strategies are developed and applied to individual problems. I argue that more successful management of invasive species could be achieved by fully integrating invasion management into restoration planning processes.

My ongoing research investigates major estuarine restoration programs throughout the world to determine whether and how invasive species management is integrated into the restoration planning process. My major goal is to determine how restoration programs can best accomplish an integrated invasive species approach that addresses all stages of invasive species management: prevention, early detection and rapid response, and eradication and control of spread. A second goal is to develop means to determine which of the potential invaders are likely to disrupt ecosystem processes. I am developing a list of criteria to guide restoration programs in determining species of concern; these criteria will be applicable across restoration programs, regardless of size or ecosystem. Research techniques include reviewing planning documents and interviews of restoration program managers.

This research is motivated and partially funded by the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP). According to the U.S. Commission on Ocean Policy's (USCOP) 2004 Report *An Ocean Blueprint for the 21st Century*, and the Presidential Administration's response — as described in the U.S. Ocean Action Plan (USOAP), invasive species prevention and management is an area of concern and consequently is among the new initiatives outlined in the Action Plan. Included in the invasive species initiative are several science and policy research programs aimed at developing new prevention, response, and management techniques. As a federally-funded initiative, the restoration program being developed by the Puget Sound Nearshore Ecosystem Restoration Project is being responsive to the President's Action Plan and to the report of the USCOP by taking early, voluntary, and pro-active steps to consider ways in which invasive species planning can be integrated into regional-scale restoration programs.

Our findings will help to guide PSNERP's ongoing restoration planning for the Puget Sound nearshore.

Solution Holes in the Rocky Glades Region of Everglades National Park: Sources or Sinks of Nonindigenous Fishes?

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The Rocky Glades region of Everglades National Park is the only intact remnant of a large karstic, short-hydroperiod marsh in the Everglades ecosystem. Historically, solution holes (dissolved limestone depressions) throughout this region likely provided dry-season refuges for aquatic animals, serving as the source of colonists upon re-flooding of the marsh surface. Compartmentalization of the Everglades ecosystem through the construction of an extensive canal and levee system has had a significant impact on Everglades hydrology, decreasing sheet flow and dramatically reducing hydroperiods in the Rocky Glades region. In recent years, the incidence and relative abundance of nonindigenous fishes in the Rocky Glades' dry-season refuges have increased markedly, especially *Hemichromis letourneuxi* (African jewelfish) and *Cichlasoma bimaculatum* (black acara). These cichlids, however, are notably less common on the marsh surface after re-flooding. It is unclear whether under current water management practices, solution holes serve as sources of marsh colonists upon wet-season re-flooding, particularly a source of nonindigenous species.

In this study, we compared the community structure and abundance of fishes in solution holes at the end of the dry season with those of fishes on the surface of adjacent marshes upon wet-season re-flooding. Communities were sampled weekly in 2002-2004: in solution holes throughout the dry-season (winter/spring) using 3-mm wire mesh minnow traps, and on the marsh surface throughout the wet season (summer/fall) in 100-m drift fences with embedded 3-mm wire mesh minnow traps. While the community structure of shallow (< 40 cm max. depth) and medium (41-80 cm max. depth) solution holes at the beginning of the dry season is similar to the community found on the marsh surface (dominated by native species), these holes dried annually, resulting in 100% mortality. Communities surviving to the end of the dry season in deep solution holes (≥ 80 cm max. depth) were dominated by *H. letourneuxi* and *C. bimaculatum*, species likely more tolerant of poor water quality conditions. During the course of the dry-season, as water levels receded, dissolved oxygen levels decreased dramatically providing an increasingly adverse environment for fishes. The degree of similarity between fish communities in solution holes and marsh habitats varied among study years. In the 2002-2003 dry-season, water levels remained higher than the 2003-2004 dry-season, resulting in a larger number of holes remaining flooded at the end of the dry season, and a similar community structure among solution holes and marshes. In contrast, the 2003-2004 dry-season was more severe, and all but two solution holes dried completely. The community structure of these solution holes at the end of the dry-season was significantly different from that on the marsh surface upon re-flooding.

Nonindigenous Fishes in Subtropical Wetlands: Impact of Wetland Restoration on Community Structure, Abundance and Diversity

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Minimizing introductions and impacts of nonindigenous species is an important goal of Everglades restoration. Over 50 species of nonindigenous fishes have been introduced in Florida with the potential to adversely affect native fish communities. While most studies on nonindigenous fishes in South Florida have taken place in Everglades National Park and the coastal canal system, the influence of these fishes in the Big Cypress system has been largely unexplored. Understanding the dynamics of fish communities in this system is important to successful restoration as they are an integral component of the food web, serving as a primary food source for wading birds. The Seminole Tribe of Florida has undertaken several wetland restoration projects on the Big Cypress Reservation, rehydrating impoundments by pumping water from adjacent canals. These include wetland restoration as part of USDA's Wetland Reserve Program (WRP) and the construction of wetland impoundments by the Water Conservation Plan, a primary component of the Comprehensive Everglades Restoration Plan (CERP).

In this study we compared native and nonindigenous fish community patterns between a newly re-flooded wetland and nearby natural wetlands. Three wet prairies and three cypress swamps in both the restored wetland and natural wetlands were sampled using minnow traps, gill nets, and 0.5-m^2 throw traps. We also tested the effects of low water temperatures on nonindigenous and native fishes to delineate the role of low-temperature stress on survival in the restored wetland.

Overall, relative abundances of nonindigenous fishes were low in the restored wetland, and abundances of small native fishes increased dramatically with rewetting. However, when specific assemblages within the fish communities were examined separately, greater influences by nonindigenous species became apparent. Assemblages of large fishes in the restored sites were dominated by nonindigenous cichlids, particularly black acara (*Cichlasoma bimaculatum*); whereas in natural wetlands large fish assemblages were dominated by native centrarchids (sunfishes). Two nonindigenous species not previously known to occur in the Big Cypress region, the Brown hoplo (*Hoplosterum littorale*) and pike killifish (*Belonesox belizanus*), were also documented in the restored and natural wetlands, respectively. Low-temperature stress was found to induce mortality in nonindigenous cichlids in shallow, wet-prairie habitats. These results may be useful to both land managers and biologists trying to limit nonindigenous species introductions in wetland restoration sites.

The Adaptive Life History of an Invasive, Euryhaline Hydroid, *Cordylophora caspia*

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An often overlooked invasive species in brackish and freshwater systems is the colonial, euryhaline hydroid, *Cordylophora caspia* (Pallas). This hydroid originates from the Caspian and Black Seas, and its distribution has expanded globally because of transport in ballast water, increased boat travel, and the hydroid's ability to acclimate and proliferate in varying salinities. *Cordylophora* coexists and colonizes zebra mussels attached to docks and offshore shipwrecks in southern Lake Michigan.

Previous life history studies of *Cordylophora* focus on brackish populations. Because limited information exists for freshwater populations, a better understanding of this hydroid's life history including seasonal variation in upright height, reproduction, feeding biology and dormancy will provide insight in to how this organism is able to adapt and spread as an invasive species.

The purpose of our work was to: 1) assess seasonal influences on growth (upright height), gonophore production, prey consumed and dormancy (the presence of menonts) for a population of *C. caspia* located in Lake Michigan, Chicago, IL. U.S., and 2) address the effects of salinity on regeneration capabilities of dormant portions (menonts) from a freshwater (Lake Michigan, Illinois) and a brackish (Squamscott River, New Hampshire) population.

To assess seasonal influences on a freshwater population of *C. caspia*, hydroid colonies were collected during 2004-05 and preserved on a bi-monthly/monthly basis from docks at Burnham Harbor, Lake Michigan. Water temperature was recorded for each sampling date. For each sample, the height of sixty uprights and the prevalence of hydranths (feeding polyps) and gonophores (reproductive polyps) were recorded. Two hundred hydranths were dissected to determine prey size and type. Upright height and gonophore reproduction increased during July and August, but decreased in the fall/winter most likely due to brittleness of *C. caspia* coenosarc or energy allocation toward reproduction in the summer months. Prey diversity was seasonal; higher prey counts were present in warmer months due to the abundance of zebra mussel larvae. Cladocerans, harpacticoid copepods, and chironomids were also consumed.

Regeneration from dormancy (induced in the lab) in a freshwater and brackish population in various salinities (0, 4, 8 and 12 psu) was studied. The freshwater population did not regenerate from the dormancy menont stage in any of the treatments (including the control). However, previous experiments demonstrated that dormant portions from Lake Michigan did regenerate across various salinities suggesting that length of dormancy may be important. The brackish population regenerated in all salinities indicating that the brackish population may be better adapted to major environmental changes that occur when this organism is introduced to a new area. The menont stage of *Cordylophora*'s life cycle is a critical aspect for the successful spread of this invasive species in both freshwater and brackish habitats. Obtaining a greater understanding of this organism's life cycle will allow us to assess the ecological impact of this invasive species in brackish and freshwater communities

Potential Harmful Algae In Tampa Bay (USA), Ballast Water Investigations Using a Dinoflagellate Cyst Model

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Ballast water exchanges in port waters have been noted as probable vectors for the introduction of invasive micromarine and macromarine species. One of the goals of this three-year project was to assess the potential for introduction of harmful microalgae from ballast water exchange by foreign vessels in Tampa Bay waters. Various species of harmful algae have been known to form cysts and remain in this state for extended periods of time.

The ballast tanks of foreign vessels, as well as the two prominent shipping ports in the Tampa Bay area, were sampled between October 2003 and March 2006. Seventy-four foreign vessels were boarded, and a total of sixty ballast water and ballast sediment samples were collected. Ships were boarded in cooperation with the United States Coast Guard, which allowed access to the ships' documents regarding ballast water exchanges and the ballast tanks. Ballast tanks were sampled through a sounding pipe or an open access hatch. Various collection methods were used depending on tank design and water level. Seasonally, water and sediment from the Port of Tampa and Port Manatee were sampled by collecting verticle net tows and petite ponar sediment grabs. Port and ballast samples were processed for dinoflagellate cysts using light microscopy and a sodium polytungstate density gradient methodology. Cysts and cyst-like cells were recovered from twenty-eight of the ships sampled and from every port ponar grab. To date, approximately 1,800 cysts and cyst-like cells have been isolated from the ballast of foreign vessels and 3,400 cysts and cyst-like cells have been recovered from port samples. Isolated cysts were incubated under approximate environmental conditions consistent with Tampa Bay. Of the cells isolated, a total of 154 have excysted from ballast samples and 686 cells have excysted from port samples. Cysts and excysted cells were photographed with a digital camera at 64x for identification purposes. Currently four species, *Calciodinellum levantinum*, *Alexandrium balechii*, and two unidentified Scrippsielloids, have been established into clonal cultures from sediments collected in ballast tanks.

Whole water samples were also examined for living microalgae that may pose an enviromental threat to another port should they exit Tampa Bay via ballast waters. In all fifteen species of dinoflagellates, four of which are considered to be toxic/harmful, as well as nineteen species of other taxa were identified. All fifteen species have previously been found in Tampa Bay waters and several have caused fish mortality events, red tides etc etc A majority of vessels reported open-water exchange outside of the Exclusive Economic Zone and used the United States Coast Guard Ballast Water Reporting Form, thereby decreasing the likelihood of introducing invasive coastal species.

Effectiveness of Ferrate (FeO_4^{-2}) as a Ballast Water Disinfectant

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Over 21 billion gallons of ballast water are released into United States waters each year. In marine systems, especially ports, estuaries, and coastal waterways, discharged ballast water from transoceanic ships is a major cause of invasive species introductions. In the United States alone, over 300 invasive species have been established in coastal ecosystems by ballast water discharge. Efforts are currently underway worldwide to find the most cost-effective method of complete ballast water disinfection that causes no harm to the environment. Ferrate (FeO_4^{-2}) has the potential to be both cost-effective and environmentally sound.

We tested the ability of ferrate to kill a wide diversity of common ballast water species. Taxa examined included: dinoflagulates, diatoms, microalgae, sea urchin eggs and larvae, barnacle nauplii and larvae, brine shrimp, bryozoan larvae, macroalgae, and marine rotifers. A range of dosages and exposure times were tested to find the minimal treatment for 100% mortality. Ferrate effectiveness was also tested at a range of salinities (15, 25, 35 ppt) to mimic exchanging ballast water in both estuarine and oceanic ports. Solutions that facilitate the safe transfer of ballast water and prevent the movement of non-native species among ports are desperately needed on our increasingly global economy.

The Impact of Invasive Plant Species on Biodiversity. The Significance of the Soil Seed Bank

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Biological invasions by alien species have been the object of many studies over the last few decades due to their ecological and economic importance. Less attention has been directed towards an understanding of the impact of invasive species on the soil seed bank or the role of seed banks as reservoirs of biodiversity for habitat restoration. The accumulation of viable seeds in the soil seed bank and alterations in soil seed bank richness, composition and abundance could be major factors determining the success of certain invasive species. The major focus of our study was to evaluate the impact of three invasive species (*Heracleum mantegazzianum*, *Gunnera tinctoria* and *Fallopia japonica*) on the soil seed bank. In Ireland these species are associated with wetland habitats and water, coupled with human disturbance, is the main dispersal agent. Assessment of the impact on the seed bank associated with the invaders was investigated using the seedling emergence approach. A complete block design was adopted and 1,850 soil samples (n=20) were collected in May and October for two years from nine sites. In order to provide information on the spatial distribution of seeds and their persistence in the soil, samples were sorted according to their depth into three categories. Results showed that species richness significantly declined in the seed bank at each depth, the impact being species-specific and site-dependent. Seedling abundance of native species declined in the invaded seed banks and species composition was profoundly altered at each site. *H. mantegazzianum* comprised approximately 55% of the seed bank at the time of sampling, with a mean value of 9,630 seedlings m^{-2}. *G. tinctoria* represented approximately 52% of the invaded seed banks, with a mean value of 38,552 seedlings m^{-2}. *F. japonica* did not produce viable seeds. Invasion by *H. mantegazzianum* lead to a decrease in the number of seedlings of grasses and herbs of approximately 76% and 52%, respectively. For *G. tinctoria* there was a decline of 83% for grasses and 61% for herbs. Invasion by *F. japonica* lead to a decrease in the number of seedlings of grass species of approximately 70% and herbs of 40%. An increase in the number of seedlings of *Juncus* spp., particularly *J. effusus* and *J. bufonius*, was recorded at sites where they were not present in the standing vegetation. Observation of seed germination patterns, based on the timing of germination and depth-dependent analysis, indicated a transient seed bank for *H. mantegazzianum* (*sensu* Thompson). In contrast, *G. tinctoria* formed a large, persistent seed bank, with significant implications for the control and management of this species. Colonisation by all the species examined lead to a significant decline in richness and abundance of native species in the standing vegetation. *F. japonica* recorded the highest impact on the standing vegetation, with a decrease in species richness of approximately 95%.

Diet Composition and Daily Feeding Activity of the Monkey Goby (*Neogobius fluviatilis*)

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The monkey goby (*N. fluviatilis*) is the newest Ponto-Caspian gobiid invader in the Baltic basin. In 1997 the species was found for the first time in the middle section of the Bug River in Poland. Since then there were no further recordings of that species in Polish waters, until in 2001 we have found it in the Vistula, the major Baltic River in which it expanded its range down to the mouth section. The diet spectrum of the species was analysed on three stations in the Vistula and Bug rivers, supplemented by the study upon its daily feeding activity in the Vistula River. Generally, the monkey goby was found to be a typical bottom feeder of predominantly nocturnal activity. Its diet composed of three main components: Crustacea, Diptera larvae and Oligochaeta. Among crustaceans, Ponto-Caspian invasive amphipods were the most prominent fraction, and dipteran larvae consisted mostly of Chironomidae. The results will be discussed and compared to information on the species feeding habits in its native range.

Invasive Amphipods in the Diet of European Perch (*Perca fluviatilis*)

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Amphipods form an important part in diet of many fishes. In recent years, the amphipod fauna of Europe has undergone major changes due to mass invasions of various Ponto-Caspian and North American species. In many cases the alien amphipods establish vivid populations in waters where local species cannot thrive because of not suitable water quality. Thus, from an ecological and economic point of view it is important whether the newcomers are included into local food webs, particularly as a new element in diet of local fish species. However, most analyses of fish diet treats all amphipods of various families together as one category or, often erroneously, as *Gammarus sp*. That makes unclear what is the real contribution of particular (especially alien) species to the fish diet. European perch is a common species in all Central and Western European waters being also an important commercial and game species. However adults are piscivorous, the young stages feed on invertebrates. Our analyses of nearly 200 young perches from the Vistula and Oder systems revealed that fish fry, insect larvae and crustaceans are the main food items. Among the latter two, Chironomidae and Amphipoda are the dominant fractions. Altogether, four species of Ponto-Caspian amphipods were detected in the diet. They were *Pontogammarus robustoides*, *Dikerogammarus haemobaphes*, *Dikerogammarus villosus* and *Chelicorophium curvispinum*, all of Ponto-Caspian origin. Our qualitative and quantitative results indicate that in the several study sites the invasive amphipods consisted and important element of the perch diet in terms of frequency, abundance and percentage of biomass.

Ship Ballast Water Studies at Carderock Division Naval Surface Warfare Center

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Scientists and engineers at the Carderock Division Naval Surface Warfare Center (NSWCCD) are engaged in several research efforts investigating ship ballast water and sediment as vectors for the introduction and spread of nonindigenous species in coastal and freshwater ecosystems, and emerging ballast treatment technologies. The work draws on the Division's significant expertise in shipboard environmental engineering, microbiology, hydrodynamics, and naval architecture. Studies include the characterization of ballast tank contents for Department of Defense (DoD) vessels, modeling of ballast water exchange, and the evaluation of heat, high-power ultrasound, and combined systems as control technologies. Our sponsors include the National Oceanographic and Atmospheric Administration, the U.S. Fish and Wildlife Service, the DoD's Strategic Environmental Research and Development Program, and the Office of Naval Research.

The poster will be a composite of past and present accomplishments in these research and development areas:

Characterization of Ballast Tank Contents. In collaboration with the Smithsonian Environmental Research Center, the Space and Naval Warfare Systems Center – San Diego, and North Carolina State University, we recently completed sampling and analysis of zooplankton (> 80 µm) communities in the ballast tanks of DoD oilers and cargo vessels. Samples from multiple tanks on 28 vessels arriving to both coasts indicated that zooplankton concentrations were typically very low, and often varied substantially among tanks aboard the same ship.

High-power Ultrasound for Treatment of Ballast Water. With funding from the Office of Naval Research, NSWCCD is investigating the effects of high intensity ultrasound on the viability of aquatic species. The prospective treatment system utilizes the new magnetostrictive alloy TERFENOL-D to cause cavitation in wastewater flows. Benchtop and limited pilot-scale testing has been conducted on bacteria, phytoplankton (in collaboration with North Carolina State University), and zooplankton, with promising results.

Modeling of Ballast Water Exchange. In partnership with the Great Lakes Environmental Research Laboratory, the development of an experimentally-validated computational fluid dynamics (CFD) model of flow in a bulk carrier ballast tank that can be used to study fluid flow dynamics during ballast water exchange is advancing. A validated computational flow and mixing model will provide interested parties (researchers, naval architects, ship owners, masters, port authorities, lawmakers) a tool to better understand the fluid dynamics occurring in ballast tanks, predict the efficacy of ballast exchange as an AIS management and treatment practice, assist with the design and implementation of treatment technologies, track and minimize the accumulation of sediments, and identify deadspots (i.e., areas where water does not mix, exchange, or flush during ballast exchange) and other flow phenomena in these tanks.

Waste Heat as a Control Technology. NSWCCD has performed a feasibility study on the potential utility of thermal energy derived from a combination of waste and auxiliary heat to rapidly treat ballast water onboard commercial ships. The feasibility of this treatment approach was investigated from both an engineering and economic standpoint.

This poster will also highlight a newly funded project to develop a methodology for creating a ballast water-specific technology assessment process. This process will be designed to be used by all regulators and implementers of ballast water treatment technology, to ascertain the state of readiness of a particular technology and its suitability for a specific ship class.

The Potential for Spread of *Lygodium microphyllum* Spores by Herbicide Applicators

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Old World climbing fern (*Lygodium microphyllum*) has become on of the worst invasive plants in Florida within ca. 40 years after first being documented in the State. Clothing and equipment of herbicide applicators were swabbed with 1-inch square cotton swabs following work in areas infested with *Lygodium microphyllum* to determine if workers and their equipment contained spores. Swabs were placed in Petri dishes in water and monitored for germinating spores. Samples were collected from workers clothing (e.g., gloves, pants, shirts, hats, etc.), backpack sprayers, machetes, chain saws, swamp buggy, and tracked ATV's. We detected *Lygodium microphyllum* spores from workers clothing, equipment, and vehicles used during treatment of *Lygodium microphyllum*. When moving to new treatment areas, we suggest that applicators thoroughly clean equipment with high pressure water or air sprayers to remove spores. Clothing worn by applicators should also be cleaned before working in a new area.

The Development of Regulation Zones as a Tool to Improve Management of Invasive Alien Freshwater Fishes in the Cape Floristic Region, South Africa

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The Cape Floristic Region (CFR) is one of the world's six floral kingdoms and is the only one confined to a single country. It is a global hotspot for biodiversity conservation with exceptional levels of biotic diversity and endemicity, and high numbers of threatened animals and plants. The CFR has relatively few indigenous freshwater fish species (19) but 16 of these are endemic and all are threatened. The major threats to these fishes are invasive alien biota and habitat degradation caused by physical and chemical impacts.

At least 16 species of alien freshwater fishes are established in the rivers and impoundments of the CFR. Most alien fishes were introduced into CFR waters between 1890 and 1970, when the policies of the authorities was to promote alien fish species for angling purposes and as a source of food. Several species are now the backbone of the recreational fishery in the CFR.

Managing these alien invaders has long been a problem in the Western Cape Province (which comprises 80% of the CFR) of South Africa. Until recently, conservation authorities were inhibited by weak and conflicting legislation, insufficient manpower and poor relationships with organized angling. There was little control over the movement and stockings of alien fishes. These problems were not unique to the province and were shared by the other eight provinces.

Positively, South Africa has a new National Environmental Management Biodiversity Act (NEMBA, 2004) and a task team has been established to develop regulations for management of alien species across all nine provinces. A key component of the regulations for invasive alien fish species are the identification of management zones for important recreational species such as carp *Cyprinus carpio*, smallmouth bass *Micropterus dolomieu* and rainbow trout *Oncorhynchus mykiss*. Within approved zones, angling for the specific species will be promoted and they can be stocked. Outside of the zones, anglers will be required to practice catch and kill and no stocking will be permitted.

The development of regulatory zones is an inclusive process, and in the Western Cape Province has been characterized by very good co-operation between Cape Nature and the major freshwater angling organizations. Examples of maps of zones for rainbow trout and smallmouth bass are included in the poster.

Cichlids in Florida: Nonindigneous Fishes Invading a Changing Landscape

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Of the more than 30 nonindigenous fishes introduced and reproducing in inland waters of Florida, at least 20 species are members of the family Cichlidae. At present, more cichlid species occur in Florida than in any other state in the continental United States and they now represent the fourth most speciose family residing in Florida fresh waters. Cichlids established in the state include five species from South America, seven species from Middle America, and six (possibly more) species from Africa. Five additional species were previously reported from the state, but these failed to become established. The complex factors that determine the extent of interactions, competitive or exploitative, between cichlids and indigenous Florida fishes are not well understood. Although the native fish fauna of Florida appears resilient enough to buffer current impacts from introductions, this may not be the case in the future. As part of our investigations on fishes introduced into the United States, we are finalizing a publication on the cichlids of Florida. The primary objectives of the publication will be to provide a practical identification guide to Florida cichlid fishes, document what is known of the initial introduction and current distribution of each species, and discuss various aspects of their life histories as well as any known or potential negative effects.

Global Information Databases on Golden Apple Snail at Your Fingertips

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In the recent years, the golden apple snail (GAS), *Pomacea* spp. has become a dreaded pest of rice, taro and other aquatic plants and listed as one of the 100 World's Worst Invasive Alien Species as identified by the Global Invasive Species Group Database (ISSG, www.issg.org/database). GAS is getting more attention due to its rapid and new invasions in Asia and North America. FAO estimates a loss of USD $1.2 billion from its infestations. The hidden cost such as loss of biodiversity, pollution of the aquatic environment from pesticide misuse/abuse, and health hazards to wetland farming communities are enormous, but not quantifiable. Important issues to manage this invasive alien aquatic pest species were addressed in collaboration with countries having history of GAS invasions by developing a global scientific information database in readily accessible electronic format, as well as on websites. These on-line databases are freely accessible for awareness, management, and source out possible funding for resource managers, decision-makers, and interested individuals such as donors, researchers, regulatory personnel, environmental groups, import/export businesses, and local governments. For remote areas where interconnectivity is absent, the Golden Apple Snail CD-ROM provides a ready solution on any aspect of GAS research with its more than 400 full-text articles covering three decades of GAS literature, searchable by author, title, year, publication, and keywords. Collections of many libraries are included. It is linked to the URL http://www.invasivespecies.nbii.gov./goldenapplesnail.html and a dedicated pest alert section at http://www.applesnail.net with multilingual versions of resources.

Developing and Implementing Effective Management Plans and Programs

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Sri Lanka is an island in the Indian Ocean covering a land area of approximately 65,610 km^2. Despite this small size Sri Lanka harbours variety of plants, animals and micro organisms. Today Invasive Alien Species (IAS) can be considered as one of the major threats on this rich biodiversity greater than ever before. Even though, the introduction of IAS to Sri Lanka goes back more than hundred years, national level attention has not adequately paid on this issue until recent past. Out of the all invasive species found in the country the impact caused by the Freshwater Aquatic Invasive Species (FAIS) is significantly high.

As a country which has signed and ratified the Convention on Biological Diversity, Sri Lanka is obliged to prepare effective conservation strategies, plans and programs to protect and safeguard country's rich biodiversity from IAS. Preparation of the national list of invasive alien plants in Sri Lanka in 1999 can be considered as important national level initiative. Sri Lanka held the first national workshop and symposium on IAS in 1999. This workshop formulated a comprehensive set of recommendations for future actions related to IAS in Sri Lanka. The recently updated national list of invasive plants consists of 20 species of which 7 species are freshwater and freshwater associated. Six species have been listed in the IUCN Hundred of the World Worst IAS List. Apart from the national list, there is a draft 2nd list comprising 14 plant species which show potential invasive characters.

The development of regulations to control and eradicate FAIS in Sri Lanka is still at the age of infancy. Nevertheless the Water Hyacinth Ordinance which was enacted in 1909 to prevent the introduction and spread of water hyacinth in the country. The provisions of this ordinance could be extended to any noxious plant to curtail them. In Sri Lankan context, amending the Water Hyacinth Ordinance when and where necessary and strengthening of the other regulations, i.e. Plant Protection Act No 35 of 1999 and Customs Ordinance are significantly important. The recent development of the addendum to the Framework Biodiversity Conservation Action Plan has paid greater emphasis on impacts of IAS.

At present, the Biodiversity Secretariat of the Ministry of Environment conducts a FAO funded project to control FAIS in the country. This project mainly focuses on two administrative districts Kurunegala and Anuradhapura of the country where thousands of larger and minor tanks are infested with FAIS such as *Eichhornia crassipes*, *Salvinia molesta* and *Pistia stratiotes*. This project carried out a preliminary survey in the above two districts. The development of future management plans to control FAIS in these districts will be based on these findings. Bio-control of *E. crassipes* using biological agents, *Neochetina eichornia* and recently introduced *N. bruchi* has achieved a notable success. But yet the country seeks an effective integrated method to control FAIS in these water bodies. Apart from that the country needs a national strategy and an Action Plan for management of IAS with special emphasis on FAIS.

Assessing the Spread of Zebra Mussels in the St. Croix River Using Density Measurements and Native Mussels

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The St. Croix National Scenic Riverway was the first unit of the National Park System, included in the Wild and Scenic Rivers Act of 1968. The Riverway is considered a nationally significant resource for its richness and abundance of freshwater mussels (~40 species, the greatest in the Upper Mississippi watershed) and is recognized for its outstanding recreational and biological assets. The diversity of unionids within the Riverway is well documented and many threats to that diversity have been identified. This faunal group will be severely impacted by a zebra mussel infestation and from other exotic invasions. Freshwater mollusks are a keystone faunal group of freshwater systems and their potential loss is unacceptable.

In order to understand the invasion of zebra mussels into the St. Croix, measurements of density were taken within the known infestation zone (the last 21 miles of river). Anecdotal evidence from the upper Mississippi River suggests zebra mussel colonization predominates on native mussel beds, especially when substrates are less favorable for recruitment (e.g., sand, silt, etc.). Therefore, sample locations were chosen based on native mussel bed survey work previously conducted by the second author. Six locations were identified from Stillwater, MN, to Prescott, WI, reflecting the range of habitats and hydrology found in the infestation zone. Thirty 1/8-meter quadrate samples were collected by divers at each of the locations. These samples were processed off river, frozen and examined under magnification. Data collected will aid managers who are creating policy based on the spread and intensity of the invasion.

The presentation will showcase the methods established to determine zebra mussel densities on the lower river, and present results of not only this invasive, but of Asian Clams and snails found during the sampling events. It will also highlight management decisions resulting from this information.

Early Detection, Status, and Trends Monitoring of Introduced Fishes in Everglades National Park

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Introduced fishes currently impede fulfillment of legislative mandates and management objectives in Everglades National Park (ENP). Everglades National Park was established as a permanent wilderness preserving essential primitive conditions including the natural abundance, diversity, behavior, and ecological integrity of its native flora and fauna. However, by the mid 1980s, seven species of introduced fish had become established in ENP. Since 2000, six additional species of introduced fishes have been collected or observed during research and monitoring studies in ENP, demonstrating renewed colonization of the region. These species were established in the canal system east of the Everglades before moving into the park. The timing of these introductions has coincided with structural and operational changes in the South Florida water management system, such as the Interim Operational Plan (IOP), that redirected water deliveries in an attempt to protect endangered-species habitat and re-water drained wetlands. Those actions appear to have aided the dispersal of the fishes. Several sampling programs have provided information on introduced species, however the distribution of sampling sites has varied among years and effort has been limited in some areas of ENP. Additional restoration initiatives and water delivery projects are being developed demonstrating the need for consistent monitoring efforts. Our goal was to establish a park-wide network of sample sites that may be used to detect the presence of and monitor the distribution of introduced freshwater fishes in Everglades National Park. We integrate results from previous year's collections with the park-wide network of sites from 2004 and 2005 to indicate changes in the distribution of introduced fishes over the past 6 years and discuss the future needs for monitoring introduced fishes.

When introduced fishes enter the park, some disperse and increase in numbers quickly, while others exhibit slower expansion and population growth. Of the newly recorded species in ENP, the African jewelfish has expanded in range and numbers rapidly whereas the jaguar guapote cichlid has progressed more slowly and typically near deep water refuges. These differences may relate to the adaptability of each species to available habitats. Marshes near canals tended to have higher proportions of introduced species than marshes distant from canals. Additional species (e.g., Asian swamp eel, various cichlids) are established in the border canal system from which dispersal into ENP is likely.

To meet the purpose and management objectives of ENP, it is necessary to move beyond the "checklist" approach and use monitoring as a tool for proactive management of introduced fishes. Rapid response depends upon early detection. Our redevelopment of monitoring within ENP puts a focus on introduced fishes. Unfortunately canals that border ENP are presently surveyed only sporadically and rapid response protocols are not in place. Monitoring these waters regularly would greatly increase early detection of introduced species that threaten ENP and may promote opportunities for collaborative efforts among state and federal agencies to control introduced species. Use of status and trends data of current introduced species may be used to develop risk assessments to identify species of special concern and promote prevention of their introduction. Proactive monitoring is both a means to track threats as well as provide early response opportunities to control invasive species in Everglades National Park.

A Risk Assessment of the Clubbed Tunicate *Styela clava* in New Zealand

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The clubbed tunicate *Styela clava (Styela)* is a sedentary filter-feeding invertebrate native to the North Western Pacific. Hull fouling is a key transport pathway for *Styela*, and it has been introduced to various locations in the Northern Hemisphere (e.g., the English Channel, the Irish Sea, New England, the Baltic Sea, Nova Scotia) as well as a handful of localities in Australia (e.g. Port Philip Bay, Victoria). *Styela* has a demonstrable invasion history, and has been especially problematic as a high-density fouler of commercial aquaculture and fishery equipment. Given the invasion potential of this organism, its discovery in Auckland and Lyttelton in late 2005 prompted an incursion response by Biosecurity New Zealand. As part of this response, we undertook a risk assessment of *Styela* that addressed the consequences and likelihood of the organism's effects on core values (environmental, commercial, Maori cultural and spiritual values, human health, and social). We identified ten core value subcomponents, and for each assigned a consequence and likelihood value (e.g. Moderate and Unlikely, respectively), or range of values, based on lines of evidence and uncertainties regarding *Styela's* potential effects. We then characterized risk (Extreme, High, Moderate, etc.) based on consequence-likelihood combinations. The assessment indicated that *Styela* poses an Extreme risk to New Zealand's marine aquaculture (esp. mussels); risks to other core value subcomponents tended to span across multiple categories (e.g., Negligible to Moderate risk to biodiversity) because of high degrees of uncertainty surrounding the organism's biology and ecology.

Physiological Ecology of the Chlorophyte *Caulerpa brachypus*, an Invader of Deep Coral Reef Habitats Off Southeast Florida

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Species in the chlorophyte genus *Caulerpa* are well known for their invasive characteristics, especially *C. taxifolia* that successfully invaded the Mediterranean Sea in recent decades. In coastal waters off Riviera Beach in southeast Florida, divers discovered *C. brachypus* var. *parvifolia* overgrowing scleractinian corals, soft corals, sponges and other emergent biota on deep (24-43 m) reefs in May 2001. Since then, *C. brachypus* has spread to other deep reefs between Boynton Beach and Jupiter, FL, reaching nearly 90% cover on some reefs by August 2004. Biochemical analysis of *C. brachypus* tissue C:N:P data, collected quarterly from two reefs sites (Princess Anne, North Colonel's Ledge) in 2003/2004, indicated both N- and P-limited growth. For example, the C:N ratio increased from ~ 10:1 to > 20:1 between winter and spring of 2003, while N:P ratios varied considerably, ranging from ~ 22 to 58 in 2003/2004. In general, N:P ratios > 35 are indicative of P-limited growth whereas ratios < 30 are indicative of N-limited growth. Controlled DIN (DIN = ammonium + nitrate) uptake studies in the laboratory showed that ammonium was assimilated by *C. brachypus* at rates from ~ 10% (at 1.0 µM) to ~ 150% (at 16.0 µM DIN) faster than nitrate when both N forms were available at equal concentrations. Manipulation of DIN concentrations within the experimental range (1.0-16.0 µM DIN) had significant, direct effects on both relative and absolute DIN uptake rates. Temperature had no significant effect on relative DIN uptake rates, but did have a direct linear effect on overall uptake of DIN within the experimental range (18-28˚C). In seven-day, DIN-enriched laboratory growth studies, *C. brachypus* grew fastest when water temperatures were warm and irradiance was low. Growth rates of *C. brachypus* under two levels of temperature (19˚C and 28˚C) and irradiance (30 and 200 µmols photons m^{-2} sec^{-1}) differed significantly, with growth rates as high as 0.9 doublings day^{-1} at 28˚C under low light (30 µmols photons m^{-2} sec^{-1}) and as low as 0.005 doublings day^{-1} at 19˚C under high light, indicating phtoinhibition. *C. brachypus* grown with the addition of 5 µM DIN grew ~ 300% faster than controls at 28˚C under high light, compared to ~ 20% faster growth than controls at the same temperature under low light, suggesting that DIN enrichment mitigates the effect of photoinhibition on *C. brachypus* growth rate. At low temperature (19˚C), 5 µM DIN enrichment had no significant effect on growth rates when compared with controls, regardless of irradiance, and average growth rates were ~ three-fold higher under low light (~ 0.035 doublings day^{-1}) than under high light (~ 0.01 doublings day^{-1}), suggesting that low temperature stress slows metabolic processes and reduces growth rates. Hence, *C. brachypus* appears well adapted for explosive growth at warm temperatures under low light on deep reef environments, especially when ammonium concentrations are elevated to ~1.0 µM.

Detection of Apoptotic Cells to Evaluate Chemical Control Strategies in Early Life Stages

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Traditional chemical control strategies for aquatic nuisance species have focused on adult life stages. Alternative approaches that determine life stages most sensitive to a given chemical treatment were assessed in a related study. By targeting more susceptible life stages, chemical dosages can be reduced, thereby minimizing environmental impacts. Such strategies restrict recruitment to the adult population rather than eradicating the population. The concept of reducing environmental impacts while generating effective control strategies is alluring, but analysis of the treatments continues to rely on more conservative mortality parameters such as LC50s or LC99s. In this study we present a complementary approach that evaluates subacute treatment effects at the cellular level to determine concentrations that would induce cell death and interrupt *progression* to the next developmental stage, in lieu of significant short-term mortality as censused by more traditional toxicity tests. We present data comparing the number of apoptotic cells detected using a TUNEL assay in cleavage (4-64 cells), swimming blastula, trochophore, and D-shell larval stages of *Mytilus galloprovincialis* treated with either $CuSO_4$, sodium hypochlorite (chlorine), or the molluscicide Bayluscide®. Exposures were subacute (either 4 hrs or 24 hrs), and based on beginning time of exposure for post fertilization (initiated at 1 hr), 24 hr (initiated at 24 hrs) and 48 hr (initiated at 48 hrs). For post fertilization exposures of Bayluscide and $CuSO_4$ (0.2 and 7.3 ug/ml assay concentrations respectively) significant numbers of embryos with >5 apoptotic cells were induced in the earliest life stages and were observed at less than half the concentrations suggested by LC50 data (see Kennedy et al., 2005, abstract). In contrast, concentrations of chlorine at which significant numbers of embryos were detected with >5 apoptotic cells were similar to those reported for LC50 data. The results for chlorine exposures suggest that the mechanism generating mortality does not necessarily induce apoptosis. At the cleavage stages, which predominate during the first 24 hours, the significance of the number of apoptotic cells may be understated since the presence of only 1 or 2 apoptotic nuclei during cleavage may predict arrest of the life stage in invertebrates exhibiting determinative developmental patterns. For 24 hr old larvae, concentrations for 24 hr exposures were greater than those for 4 hr exposures that induced significant numbers of apoptotic cells, but were still significantly less that the LC50 concentrations for Bayluscide and $CuSO_4$. One interpretation of the treatments at later life stages would be that as development continues, not only do the stages become more resistant to the treatments, but that more apoptotic cells are required to interrupt the life cycle. This is corroborated by the observation that in treatments at 24 hr and 48 hr periods, apoptotic cells were more restricted to cells near exposed surfaces of the larval stages. Correlating effects of apoptotic cell number on recruitment to later life stages or even mortality will require additional studies following subacute treatment for significantly longer periods of time to more accurately assess the fate of larvae exhibiting >5 apoptotic cells.

The Invasion of South America by the Golden Mussel *Limnoperna fortunei* (Dunker, 1857): Population Densities in Natural and Artificial Environments

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Limnoperna fortunei (Dunker, 1857) commonly called the golden mussel, is a freshwater mytilid native of South East Asia. It is considered a freshwater invasive pest due to its adaptability to new environments and extremely high rate of colonization, forming big clusters of individuals attached by byssus in a few months. In 1965 it was introduced into the water supply system of Hong Kong; reaching Japan and Taiwan in the 1990s. In 1991 it reached the Americas. It entered the Plata Basin in South America, probably brought in the ballast water of transoceanic ships. *L. fortunei* is presently found in five countries in South America. Long term inventories on the first years of colonization have been obtained in the river basins of Rio de la Plata River, Paraguay, the upper Paraná and the Guaiba-Patos. When first detected in Rio de la Plata, the density of organisms was 4 to 5 individuals/m^2. In one year, the founding population reached a density of 30,000 individuals/m^2 and in two years 80,000 individuals/m^2. In 1995 the golden mussel density was approximately 150,000 individuals/m^2. The population density then decreased and stabilized at 40,000 individuals/m^2. In 1998, the golden mussel was found for the first time in different and distant basins in Brazil: in the Guaíba-Patos Basin in the extreme south of Brazil and the Paraguay River, Mato Grosso do Sul State. In Lake Guaíba, *L. fortunei* increased in number to a maximum density of 27,275 individuals/m^2 one year and five months after the first discovery and 62,100 individuals/m^2 in the second year. In the third year it reached a density of 143,500 individuals/m^2, then decreasing to the same levels as in Argentina. In the lower Paraguay River the mean densities of adults on natural substracts, were approximately 10,000 individuals/m^2 four years after the first record of *L. fortunei* and 41,500 individuals/m^2 one year later. In the river-connected lakes of the same Basin, the levels of densities were lower, about 20,000 individuals/m^2. The population of *L. fortunei* has just begun colonization with settling by isolated individuals having taken place since November 2004 in the upper Paraguay River, at Cáceres in Brazil's Mato Grosso State. In the artificial Lake Itaipu in the upper Parana River, the population reached the mean highest density of 54,505.21 individuals/m^2 in the 12 months following the first record. The infestation by *L. fortunei* in the natural environment of South America is characterized by a proportionally small northward reduction of the rates of population densities in each locality surveyed. The differences should be interpreted as probably related to the climatic changes in temperature of the water and other limiting factors in restricted areas. Nevertheless it advances at a speed of 240km/year against the prevailing water current, from the Rio de la Plata River toward the headwaters of the Parana-Paraguay Basin. Two years after the appearance of the golden mussel inside natural environments or artificial dams along the observed Basins severe macrofouling problems were recorded with great economic damage to the water intakes and water cooling systems of industrial, hydro-electric or nuclear power plants.

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Eco-parasitological Consequences of *Dreissena polymorpha* Spread: A Program for Future Studies

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The bivalve molluscs *Dreissena polymorpha*, zebra mussel, is among the most well known Ponto-Caspian invaders widely distributed nowadays in Europe and North America. Appearance of zebra mussel in a waterbody affects many components of its ecosystem, and numerous studies were conducted to reveal and quantify these impacts. Relatively little efforts have been made, however, to study the eco-parasitological aspects of *D. polymorpha* spread despite the fact that it is known to serve as the sole or intermediate host for many taxonomically different endosymbionts (i.e., parasites and commensals). For instance, our studies in the Republic of Belarus revealed more than 50 types of symbionts associated with mantle cavity and/or visceral mass of the mussel. Among these symbionts are pathogenic helminth parasites of fish and waterfowl (e.g., *Bucephalus polymorphus, Phyllodistomum folium, Echinoparyphium recurvatum*). It is obvious that during its own dispersal, *D. polymorpha* may serve as a vector for spread of its obligate parasites. In addition, mussels may become hosts to parasites in recipient ecosystem. As a result, all this may lead to definite change towards the worse epizootic situation in a waterbody because of increased abundance of parasites. Unfortunately, current data do not make it possible to conclude how significant such changes are. In this relation, several directions of future studies can be distinguished:

- Most previous investigations of *Dreissena*'s parasite were dedicated to local waterbodies, with disproportionately higher attention paid to waterbodies of Belarus, Ukraine and Russia. Accumulation of additional information is required to describe the geography of parasites distribution and their taxonomical diversity in different sites of the host's range.
- Besides *D. polymorpha*, its trematodes may use other molluscs as intermediate hosts as well. Therefore, the revealing of the specific contribution of zebra mussel to maintenance of trematodes populations implies synchronous estimations of the prevalence and intensity of infection in all potential hosts. These estimations should be accompanied with assessment of relative abundance of each of the hosts for subsequent comparison of densities of parasites hemipopulations per m^2 of bottom.
- Fish and waterfowl become infected with some of *Dreissena*'s trematodes (i.e., *P. folium* and Echinostomatidae) through eating infected molluscs. It is necessary to study the consumption of zebra mussel by predators compared to other molluscan hosts of trematodes.
- Many studies showed size selective consumption of zebra mussel by predators (usually small and medium-sized individuals are preferred). To predict the intensity of parasites transfer on subsequent hosts, a correlation between mean size of molluscs in a population and parameters of their infection with parasites should be found.
- Accumulation of extensive data on parasitological situation in waterbodies before and after *Dreissena* invasion is required to better understand the overall eco-parasitological consequences of its spread.

Hitchhikers Delight: Five Star Translocation of Nonindigenous Marine Species by Cruise Ships

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Much study has been made of the relative risks of ballast water as a vector of nonindigenous marine species (NIMS), but hull fouling as a vector for the translocations of NIMS is relatively poorly understood. Biosecurity New Zealand (BNZ) has commissioned a multi-year study aimed at characterizing the nature and extent of fouling communities present on a variety of vessel types arriving in New Zealand from overseas. BNZ is managing this large and complex project by assigning the sampling of different vessel types to different research providers (reported in other presentations at this conference), and by adopting a 'taxonomic clearinghouse' approach, whereby a single research provider is responsible for all identifications of material supplied from different sources. We have been contracted to survey fouling communities on cruise ships and fishing vessels arriving in New Zealand. We report here the interim results of the first seasons of cruise ship sampling, including consideration of vector pathways and general fouling assemblages.

Impact of the Zebra Mussel *Dreissena polymorpha* on the Ecological Integrity of Lough Sheelin

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The principal study site for the project is Lough Sheelin, a highly productive midlands lake on the upper Shannon catchment in Ireland. This was originally an excellent trout fishery of high water quality. However, since the early 1970s, the lake has been under considerable environmental stress from eutrophication. On top of this, the recent introduction of the zebra mussel *Dreissena polymorpha*, is now exerting an additional pressure as it becomes established in the lake. This project is attempting to assess the impact the invasive species is having on particular aspects of the ecology of Lough Sheelin. The distribution, extent of colonisation and population characteristics of the mussel are being determined over the three-year duration of the project. In addition, changes to the fish and macroinvertebrate communities as well as to physiochemical parameters and fish diet are being assessed. Over 20 years of background biological and physiochemical data are available to aid in the assessments.

Preliminary results show *Dreissena polymorpha* was present at all stone substrate sites sampled and all soft substrate (mud, silt and sand) sites surveyed less 6m depth in the lake. In addition the mussel has extensively colonised both submerged and emergent plant vegetation. On stony substrate an average biomass of 1.5 kg/m^2 and a maximum biomass 9.7 kg/m^2 were recorded. On soft substrates the mussel had an average biomass of 0.345 kg/m^2 and a maximum biomass of 0.6 kg/m^2.

Physiochemical water quality results show a reduction in annual mean chlorophyll a levels and a corresponding increase in water transparency since the zebra mussel invasion, although total annual mean phosphorus levels in the lake remain high.

Results of fish diet analysis indicate that *Dreissena polymorpha* was a constituent part of the diet of roach, roach bream hybrids, trout and perch in spring 2005 and of roach, roach bream hybrids, pike and tench in summer 2005.

Further Evidence of the Environmental Safety of the Zebra Mussel Control Agent *Pseudomonas fluorescens* Strain CL145A: Lack of Acute Toxicity to *Daphnia magna*

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Laboratory and facility trials have indicated that *P. fluorescens* strain CL145A (*Pf*-CL145A) has significant potential for commercialization as a biological control agent of zebra mussels (*Dreissena* spp.). Although phytoplankton are their preferred food, zebra mussels can also filter and consume bacteria as a food source. When a zebra mussel ingests artificially high densities of *Pf*-CL145A cells, a toxin within the bacterial cell destroys the mussel's digestive system. Dead *Pf*-CL145A cells are equally as lethal to zebra mussels as live cells, indicating that the mussels die from bacterial toxicity, not infection. Research has focused on using dead-cell formulations – a commercialization path which should further reduce environmental concerns.

In terms of environmental safety, nontarget trials to date have been very encouraging. In tests using dead *Pf*-CL145A cells, no mortality has been observed among any of the following nontargets: the ciliate *Colpidium colpoda*, seven bivalve species (*Mytilus edulis, Pyganodon grandis, Lasmigona compressa, Strophirus undalatus, Lampsilis radiata, Pyganodon cataracta, Elliptio complanata*), and three fish species (*Pimephales promelas, Salmo trutta*, and *Lepomis macrochirus*). Despite these results, it would be unreasonable to think that this strain will prove so selective as to only affect zebra mussels. For this reason, further nontarget tests are ongoing to satisfy U.S. Environmental Protection Agency (USEPA) biopesticide registration requirements. Herein we report our latest nontarget trials evaluating the acute impact of *Pf*-CL145A on the microcrustacean *Daphnia magna*. This daphnid is an aquatic nontarget organism for which the USEPA typically requires safety data prior to registration of new aquatic biopesticides. Daphnids are filter-feeders that normally ingest suspended particles such as bacteria, making them appropriate candidates for such trials.

Protocols from the USEPA for daphnid rearing and acute toxicity testing were used as guidelines and, where appropriate, supplemented with daphnid testing methodologies developed by the NYS Department of Environmental Conservation. A series of 4 tests were conducted using *Pf*-145A cell suspensions that had been produced in 100-L fermentation runs and subsequently irradiated to kill the cells. In each test, four replicates containing five *D. magna* neonates (≤24 hr old at test initiation) were held for 48 hr in covered glass Petri dishes containing 25 ml of untreated hard water (controls) or hard water which had been treated at 200 ppm, i.e., 0.2 mg of bacterial cells (dry weight) per ml. After treatment, daphnids where transferred to clean Petri dishes containing fresh hardwater where they were held for an additional 8 days. Each dish of daphnids received food and was checked for mortality daily throughout the 10-day test. Tests were conducted at 23(±1)ºC.

Test results indicated that *Pf*-145A cells were nontoxic to the daphnids when treated at 200 ppm for 48 hr. Overall mean daphnid mortality (±SD) among the 4 tests was 5.0(±5.8)% in treated dishes and 6.3(±7.5)% in controls. In contrast, concurrent tests against zebra mussels at 200 ppm for 24 hr resulted in an overall mean mortality (±SD) of 92.7(±2.4)% (control mortality 2.2(±1.7)%). These results are further evidence that this strain of *P. fluorescens* has unusual host specificity and suggest its use as a zebra mussel biocontrol agent will pose relatively low environmental risk.

The Black Carp (*Mylopharyngodon piceus*) in North America: Probable Establishment and Potential Ecological Impacts

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The Black Carp *Mylopharyngodon piceus*, native to eastern Asia, is one of several commercially important fishes often referred to as the Chinese or Asian carps (Cyprinidae). Recently (2003-2005) commercial fishers have netted Black Carp from several sites in the Mississippi River Basin. These captures were thought to be the first North American records of Black Carp in the wild, but new information indicates that the species has been periodically taken by commercial fishers working the lower Mississippi since the early 1990s. These earlier captures went unreported as fishermen mistakenly believed the fish were simply an unusual, darkly colored "Grass Carp" (i.e., *Ctenopharyngodon idella*). Reproductive requirements of Black Carp are similar to three other Chinese carps (Grass Carp, Bighead Carp *Hypophthalmichthys nobilis*, and Silver Carp *H. molitrix*) already established in North America. Based on several lines of evidence, it is probable that Black Carp also are reproducing and established: 1) new information indicating Black Carp have been in the wild more than 10 years; 2) suitable conditions for the species' entire life cycle exist (i.e., spawning and nursery areas, food resources, etc.); and 3) recent captures include diploid adult Black Carp. To date no larval or small juvenile Black Carp have been reported; however, similar to the situation with adults, it is possible that larval or juvenile Black Carp are being taken but simply overlooked or misidentified. If this species follows the same patterns of spread and colonization as other introduced Chinese carps, the distribution and abundance of wild Black Carp will increase over the next several years. Because of their size and diet specialization, presence of wild Black Carp in North American may hasten the decline of native mollusks, many of which are already declining in numbers. Analysis of Black Carp gape limits suggests many mollusks will be vulnerable to predation.

The National Aquatic Nuisance Species Clearinghouse and Searchable Database of Holdings

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Stakeholders interested in the introduction, spread, potential impacts, and control of aquatic nuisance 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 related to zebra mussels from Sea Grant's Zebra Mussel Information Clearinghouse.

A revised mission resulted in the name change to the National Aquatic Nuisance Species Clearinghouse in 1997, with expanded efforts to facilitate and coordinate aquatic nuisance, nonindigenous, and invasive species information (ANS/NIS/AIS) sharing among researchers throughout North America and worldwide; provide continuity to the timely dissemination of findings of ANS/NIS sharing among researcher 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 AIS/ANS throughout the Gulf of Maine to the Southern Atlantic, Gulf of Mexico, California to the Pacific Northwest, and Great Lakes Regions, in addition to North American inland river and lacustrine systems are now addressed. The Clearinghouse is continually updating its library and searchable database of over 7400 documents, which include specific collections on twenty eight organisms, as well as biological macrofouling, ballast water, nonindigenous aquatic species, and invasive species policy issues.

All Clearinghouse information is accessible to any individual or group via electronic mail, fax, telephone, written requests or visits to the Clearinghouse. The Clearinghouse's holdings are best accessed through the keyword outline and full text searchable bibliographic database available on its World Wide Web site (www.aquaticinvaders.org). Most documents are available directly from the Clearinghouse and can be ordered via a convenient on-line "shopping basket," which also displays the copying/mailing fee. Citations include: author(s), title, document source and date of publication, an annotation, type of publication, document length and language in which it is written. The web site also contains a series of detailed maps charting the range expansion of the zebra and "quagga" mussels in North America since 1989 as well as extensive links to other ANS/NIS web sites.

Aquatic Invaders, the Clearinghouse's quarterly publication, 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 new library holdings, useful web sites, and meeting announcements.

The Federal Aquatic Nuisance Species Task Force, U.S. 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 international agencies and institutions have utilized the Clearinghouse as a channel for extending information on aquatic nuisance, nonindigenous, and invasive species spread, research, and policy initiatives to interested audiences.

Sensitivity of Aquatic Invertebrate Resting Eggs to Proposed Chemical and Physical Ballast Tank Treatment Methods

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The introduction of aquatic species in resting life stages by the release of ballast water is a less well known but potentially important invasive species vector. Best management practices designed to minimize transport of ballast water cannot eliminate this threat because residual water and sediment are retained in ballast tanks after draining. To evaluate the potential efficacy of chemical and physical treatment of residual material in ship ballast tanks, this study examined the acute toxicity of the proposed biocide SeaKleen® (Menadione), glutaraldehyde, hypochlorite, UV radiation, and heat on resting eggs of *Brachionus plicatilis* (a marine rotifer), a freshwater copepod, *Daphnia mendotae* (a freshwater cladoceran), and *Artemia* sp. (a marine brine shrimp). Heat and SeaKleen were toxic to resting eggs of all taxa. UV radiation produced little toxic effect. Reduced toxicity of chemical biocides in the presence of sediment raises serious doubts as to the potential for this, or any, chemical biocide to kill aquatic invertebrate resting stages buried in sediment retained in ship ballast tanks.

Alien Fishes in Iberian Freshwater Ecosystems: A Recent Review

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Freshwater fishes were first introduced into the Iberian Peninsula during the XVIIth century as food and ornamental fishes but more recently most introductions have been made to support recreational fisheries. In this work we review the characteristics of introduced fishes in Spain and Portugal including species' origin, reasons and dates of introduction, establishment rates and species invasiveness. Forty five fish species were introduced into Iberian watersheds but only 22 species successfully established populations while 13 species failed to establish self-sustaining populations. In addition, 10 native fishes were translocated within Iberian Peninsula mainly due to water transfers. The oldest known introduction is the carp dating from the Hapsburg dynasty (XVIIth century) while in the most recent one is the tinfoil barb. Carp, goldfish and largemouth bass are the most widespread alien fishes in Iberian Peninsula, occurring in almost all drainages, while the most abundant species are eastern mosquitofish, gudgeon and carp. Europe and North America are the main source areas for successful alien fishes, while South America and Asia contribute relatively few aliens. Recreational fisheries is the most common reason for introductions followed by aquarium releases and aquaculture, although for some species the reason for introduction is still unknown. Bigger drainages have more alien fishes; thus Ebro drainage has the most species followed by east Catalonian rivers (an exception to this trend). Alien fishes seemed to disperse from East to West mainly due to illegal spread by fishermen especially into the highly invaded rivers of the eastern peninsula (Catalonia). In order to reduce the spread of alien fishes, recreational fishermen need to become better educated in conjunction with stronger legislation (international, national and regional) and increased law enforcement over the entire Iberian Peninsula.

Black Bullhead in a New Reservoir: An Invader Waiting for a Chance to Break Through?

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A single specimen of black bullhead [*Ameiurus melas* (Rafinesque, 1820)] was firstly detected in the Guadiana River (Iberian Peninsula) in February 2001. No further occurrences were reported until 2003, although extensive surveys were carried out in the Guadiana River basin. This basin changed dramatically due to the construction of the Alqueva Reservoir mainly since February 2002 when its floodgates were closed. Over 25,000 ha were flooded transforming a highly seasonal lotic system into a large lentic habitat. The Alqueva Reservoir is considered the largest artificial lake in Europe, with a maximum volume of 4,150 hm^3, being classified as a very shallow and eutrophic system.

Two sampling surveys were performed during autumn 2003 and 2004, using electric fishing and seine netting, to confirm and assess the establishment of black bullhead in this new reservoir. Although, the fish community was mainly composed by pumpkinseed sunfish [*Lepomis gibbosus* (Linnaeus, 1758)] during both years, there was some interannual variability in relative abundance of the remainder community elements, namely mosquitofish (*Gambusia holbrooki* Girard, 1859) and largemouth bass [*Micropterus salmoides* (Lacepède, 1802)]. Black bullhead was a relative small and constant component of this assemblage, about 2% of relative abundance in both years, although the total number of *A. melas* captured decreased from 303 to 18. During both years, black bullhead was mainly represented by small sized specimens suggesting a young population. The ultimate success of *A. melas* in Alqueva Reservoir cannot be inferred directly from our results, but the potential for the reservoir to act as source for dispersion to the remaining Guadiana basin is present and should be taken seriously.

Ballast Water as an Accidental Vector for the Introduction of Harmful Microalgae Into Tampa Bay, Florida (USA): A Project Overview

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Ships are known vectors for the transfer of nonnative harmful microorganisms through ballast water discharges into ports and harbors. Microalgae, particularly dinoflagellates, present a particular concern because they may remain viable in ballast water for weeks, and their dormant stage (cysts), have been known to remain viable for years. Florida is second only to Hawaii in the total number of exotic plants and animals and also has more species of harmful algae than any other state in the nation, some of which may have been introduced relatively recently. The results of this study provide the first preliminary assessment of the presence of nonnative harmful species in the ballast tanks of foreign ships visiting Tampa Bay and its ports.

A survey of microalgae collected from water and sediments of both ships' ballast tanks and the commercial shipping ports of Tampa was conducted from September 2003 through March 2006. Data from this survey are being used to assess the potential for the accidental introduction of nonnative harmful microalgae of known natural resource and public health consequences into Tampa Bay. Sampling protocols best suited to the local conditions, local species inventories and lists of species posing current and future potential risks were all generated. We have identified future monitoring requirements, and potential routes of introduction for invasive microalgal species.

The ballast water and sediment of sixty ballast tanks of foreign ships have been sampled by various methods in the Port of Tampa and Port Manatee. Vessel access was obtained by accompanying the U.S. Coast Guard Marine Safety Office of Tampa during their scheduled ship inspections. The port surveys consisted of seasonal sampling of the water and sediments at multiple fixed locations in both ports.

The primary approach used in this study consisted of microscopic examination and identification of viable algae and cysts of ballast and port waters, photography, single cyst isolations, and cyst incubations under local environmental conditions. Cyst incubation was used to assess cyst viability and aid in species recognition through the identification of excysted vegetative cells. To date, the incubation of approximately 5,200 cysts and cyst-like cells from ballast and port water/sediment has not yielded any algal species recognized as toxic/harmful that were not already previously known to inhabit Tampa Bay. It has resulted in at least one potentially nonnative yet to be identified dinoflagellate species, whose toxic/harmful classification has yet to be assessed. The potential for the importation of nonnative species into Tampa Bay via ballast water discharge was confirmed by the successful germination of dinoflagellate cysts from the ballast tanks of foreign ships, while the potential for species exportation from Tampa Bay was confirmed by the simultaneous presence of *Alexandrium balechii* cysts and vegetative cells in port water/sediment and cysts in the ballast tank of an outbound foreign vessel.

A secondary research objective is the development of a working protocol for sequencing the mtDNA encoded cytochrome b gene from single cysts to assist in microalgae species identification. A library of sequences from port and ballast water cysts is being assembled for use in species identifications and future molecular studies.

Invasive Species in a Desert River: Impacts on Southwestern USA Native Fishes and Plants

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A dozen native fishes historically inhabited the Verde River, Arizona. After a century of time, thousands of stocking events, and millions of individuals input into the waters of Arizona, invasive fish species are presently twice as abundant as the historic number of native species. In addition, other vertebrate and invertebrate species such as bullfrogs and crayfish, and Asiatic clam have been introduced into this desert river ecosystem Results of study over the past decade indicate the dramatic, cumulative, interactive negative impacts of these invasive aquatic and terrestrial species on the native fishes. Total numbers of fishes have declined 80% in a few years and invasive species predominate the fish assemblage. Changes in livestock management and historic floods have influenced the riparian plant communities. Scoured streambanks and floodplains become niches for invasive plants. Streambank vegetation once dominated by sedges and rushes is increasingly invaded by annual forbs. Recent surveys indicate there are over 60 species of invasive plants in the upper Verde River. Functional groups for invasive plants are identified for management.

Potential for Control of Nonindigenous Asian Swamp Eels (Family Synbranchidae) with Rotenone

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We conducted laboratory experiments to determine whether the chemical rotenone might be useful as a control against introduced Asian swamp eels (*Monopterus* spp.). The study involved tests on swamp eels of various sizes (1 to 350 g) including individuals from each of the three known Florida populations. Rotenone was found to be lethal to swamp eels at relatively high concentrations. These findings, combined with personal observations of swamp eel habitat use and behavior suggest that use of rotenone to control established populations in Florida would be difficult. However, control of other (or new) populations may be possible in certain situations, especially if rotenone is used in combination with other methods (e.g., electrofishing). Recommendations for control with the chemical and caveats associated with these are discussed.

Phytochemicals: An Environmentally Friendly Alternative to Toxic Anti-fouling Coatings

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The inadvertent spread of nonindigenous aquatic species around the world appears to be dramatically increasing. Shipping is presently considered the single largest vector for the movement of nonindigenous aquatic species around the world. A variety of biofouling organisms are capable of hitchhiking a ride attached to the inside of ballast tanks, sea chests or on the exterior of hulls. Effective anti-fouling coating containing tributyltin and copper "were" our best form of defense, however their toxic effects on the marine environment have forced the development of environmentally friendly alternatives.

Magellan has developed environmentally friendly anti-fouling additives known as "phytochemicals" (i.e., compounds isolated from botanical sources) that are capable of being incorporated into marine paints and coatings as biocides. Therefore they are compatible with leaching coatings, ablative coatings and self-polishing coatings (polymers), latex for coating aquaculture and even water-soluble polymer delivery systems for ship ballasts. Phytochemicals leach out of the paint in low concentrations and disperse extremely well throughout the water column. Furthermore, their biodegradability will ensure they do not accumulate to unacceptable levels in the environment.

To date preliminary test panels subjected to both static and dynamic conditions in Tuticorn, India and Florida, United States have maintained fouling free surfaces beyond 12 months. Organisms excluded have included (but are not limited to): parazoans, coelenterates such as polychaete and oligochaete worms; mollusks such as zebra mussels; crustaceans such as acorn and gooseneck barnacles. This safe, economical technology combines several phytochemicals that fall under the "Generally Regarded as Safe" standard of the United States Food and Drug Administration. The result of our trials will be discussed during the presentation and future research and development directions highlighted.

Limpograss Invasion in the Kissimmee River Floodplain

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Limpograss (*Hemarthria altissima*) is a stoloniferous tropical grass of the family Poaceae, and it is found in its native habitat along stream banks or seasonably wet soils in southern Africa. It was introduced into Florida as a promising cattle forage and four cultivars have since been released. Approximately 100 000 ha of limpograss have been planted for grazing and/or hay production in central and south Florida, including the Kissimee River floodplain.

Historically, the Kissimmee River was a meandering 166 km stretch of waterway consisting of a 1.6 to 3.2 km wide floodplain. As a result of catastrophic flooding in the 1940s and early 1950s, the state of Florida along with the U.S. government funded a plan to channelize the river to prevent future wide-spread flooding events. Once the 9.1 m deep by 91 m wide channel was complete in 1972, much of the flood plain was drained and diversity of desirable plant and animal species began to decline.

The loss of species diversity and increasing environmental concerns resulted in an effort to restore the river back to its native state. This prompted nearly 20 years of research on restoration in the Kissimmee River and its floodplain, which led to back-filling 35 km of the man-made canal and restoring approximately 104 km^2 of the floodplain. Within this non-residential area, the floodplain was acquired from ranchers and it is as many as 3.2 km wide, with much of this area subject to seasonal flooding.

Prior to restoration of the Kissimmee River, ranchers improved pastures near the river channel by establishing limpograss. It is estimated that over 15,000 ha was planted near the channel. However, limpograss was not recorded in the Kissimee River floodplain through biological surveys prior to restoration. After restoration efforts were concluded in the pool C section of the river, limpograss invasion began to occur. It is estimated that limpograss has infested approximately 1,200 ha where a broadleaf marsh existed prior to channelization of the river. Additionally, limpograss can be found in isolated patches in a portion of the floodplain that was a bahiagrass (*Paspalum notatum*) sod farm prior to restoration.

Although limpograss is an important forage species for Florida cattlemen, it is also important that best management practices for eradication in natural areas, such as the Kissimmee River, be developed. Experiments were established at the Range Cattle Research and Education Center to determine the most effective treatment options for limpograss control. Glyphosate (>1.1 kg ae/ha) appears to be the best option as greater than 95% visual control was observed 3 months after treatment. Other herbicides such as clethodim, fluazifop, nicosulfuron and diquat provided some reduction in limpograss growth, but limpograss appeared to recover. These results will be used to develop treatments for limpograss in the Kissimmee River floodplain in an attempt to restore the native broadleaf marsh that was present prior to channelization.

Biological Test of Plankton By *In Situ* Adaptability and Ballast Water Treatment System

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Possible introduction of foreign species through ship ballast water and the survivorship of natural population of plankton after treatment of electrochemical reactor were investigated to regulate and manage the ship ballast water discharge in the natural environment. Phyto- and mesozooplankton were sampled by vertical hauls with the standard type net (20 and 200 μm mesh, respectively) through manhole type ballast water tanks of five bulk carriers in Incheon port dock of Korea in 2005. Most identified planktons were similar to the seasonally occurring species around Korean waters except symbiotic copepod. Even though the phytoplankton is not foreign species, it can pose negative effect on the endemic plankton community when facing with their preferring environment. Therefore, recovery experiments were conducted by injection of ballast water originated phytoplankton into two types of media such as Incheon port sea water filtered through 0.2 μm mesh filter paper and F/2 media. Following time series incubation, it was evident that some species like *Skeletonema costatum* and *Leptocylindrus danicus* can grow fast in the natural seawater after being discharged rather than in F/2 media.

Following the treatment of electrochemical reactor, the survivorship of planktonic zooplankton was assessed immediately through direct observations, while phytoplankton and bacteria survivorship were assessed by immediate observations through green filter and through 48h incubations. Under the condition 5 tons/h, 2.8-3.0 V, 75 ampere (NaOcl: 10 ppm), dominant phytoplankton, *S. costatum, Ceratium fusus, Thalassionema nitzschioide*s, turned from red into green after they passed the reactor, indicating no live chlorophyll-*a* remained. And no live *E. coli* and coliform bacteria were remained after being passed through the reactor. With respect to zooplankton, live copepods were not observed in the post-reactor samples. The remove efficiency of phytoplankton and copepods was up to 100% by using the electrochemical reactor.

Space Invaders: Resistance is Futile, So Hide in the Long Grass

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The classic hypothesis first put forward by Elton in 1958 states that a community with high biodiversity is less susceptible to invasion than communities with low biodiversity, as better resource utilization creates a highly competitive environment. Increasing biodiversity in certain marine epifauna can cause an increase in structural diversity. Structural diversity may influence the success of invading species, which attach to the surface of epifaunal species such as hydroids, tunicates and bryozoans. Using the non-native amphipod *Caprella mutica*, in aquarium based experiments the relationship between invasibility, biodiversity and structural diversity was explored. Native sessile marine invertebrates are mimicked using artificial components made up of short turf (ST), long turf (LT) and mussels (M) on nine 3 x 3 structural tiles. The structural tiles were manipulated to consist of 1, 2 or 3 of the artificial components, creating seven different structural combinations and three levels of structural diversity. Each experimental trial was replicated four times and the experiment was repeated using the native caprellid *C. linearis* and equal numbers of *C. linearis* and *C. mutica* at densities of 25 and 50 individuals per structural tile per experiment.

Structural diversity was only significant when *C. mutica* and *C. linearis* at densities of 50 individuals per structural tile were released together in the same experiment ($p < 0.05$). Structural diversity consisting of the 3 components per tile LTxSTxM had significantly more caprellids of both species attached to it than 1 structural tiles LT, ST and M. No significant difference between tiles with 3 and 2 and 1 and 2 structural components was observed. Further analysis showed that *C. mutica* displaced *C. linearis* on the 1 structured tiles. Analysis of each individual component LT, ST and M for the entire 9 structural tiles was significant at densities of 25 and 50 individuals per structural tile and for all 1 and 2 species combination of caprellids. LT had significantly more caprellids attached to it than M and ST. ST had significantly more caprellids attached to it than M. Comparisons between *C. linearis* with and without *C. mutica* present showed that there were significantly higher mean abundance of *C. linearis* attached to the individual components when *C. mutica* was not present ($p < 0.001$). Further analysis showed that *C. mutica* displaced *C. linearis* from the components LT and ST and there were no differences between M. Comparison of the individual components LT, ST and M for *C. mutica* with and without *C. linearis* showed no significant difference.

In conclusion, increasing structural diversity did not affect the invasion success of *C. mutica*. *C. mutica* and *C. linearis* showed the same preference for the individual components indicating competition for space may occur. *C. mutica* was able to displace the native *C. linearis* at low structural diversity thus suggesting that high structural diversity offered a refuge for *C. linearis*. Higher structural diversity may offer community resistance against invasion by non-native species, which inhabit the surface of epifauna by providing an increased number of alternative sites for habitation.

Ballast Water Disinfection Using High-power Ultrasonic (HPU) Cavitation Driven by TERFENOL-D

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Ultrasonic technology has been utilized for over fifty years in cleaning and welding applications. In ultrasonic cleaning low power levels are required for a long duration, whereas in welding applications high-power levels for very short durations are required. As such, it is only in the last decade that ultrasonic technology has caught up with the need for applying high-power ultrasonic energy to create cavitation in a fluid on a continuous basis. The magnetostrictive alloy TERFENOL-D is one such enabling technology. Developed by the Naval Ordnance Laboratory in the 1970s for higher power sonar capability, TERFENOL-D has been incorporated into the MaXonics ultrasonic system to deliver continuous high-power ultrasonic energy to a flow stream. The high intensity acoustic fields create cavitation bubbles due to the shearing of the fluid medium. The collapse of these bubbles creates localized temperatures on the order of 9,000°F and extremely high mechanical forces: 15,000 psi and 250 mph jet streams. This mechanical and thermal energy is very effective in killing small organisms that may pose a threat to ecosystems in which they may be discharged during typical ship operations. A flow loop has been built to study the effects of ultrasonic energy to waste streams with various organisms encountered in ballast water discharge as well as bacterial organisms present in gray water. With this flow loop, marine biologists at the Naval Surface Warfare Center, Carderock Division (NSWC-CD) are able to study the effects of changing intensity, flow rate, and system pressure in order to determine whether the application of continuous, HPU cavitation is a viable alternative or possible addition to ozonation and chlorination technologies currently used aboard ships. In this poster presentation, the technical aspects of the flow system and the basic functionality and versatility of TERFENOL-D will be described.

U.S. Coast Guard Aquatic Nuisance Species Outreach Program

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One of the most important aspects in mitigating the introduction of aquatic nuisance species (ANS) is educating the public on the problems caused by ANS and solutions currently being developed. The U.S. Coast Guard Environmental Standards Division is working to educate the maritime sector, ranging from the maritime industry to the recreational boater.

Commercial vessels provide a potential means of transport and introduction of ANS in their ballast water in addition to hull and surface fouling. Regulations are continuing to be an effective tool in controlling and monitoring ballast water discharges, but it is also important to continue to provide information to the maritime industry.

To reach out to industry, several different means of outreach are employed. The Internet has proven to be a valuable communication link between the Coast Guard and the shipping industry. The Coast Guard is able to provide education and training through the Internet. The Coast Guard ANS web site is user-friendly and is kept up to date with links to current regulations, as well as guidelines to assist recreational boaters to prevent the introduction of ANS. The Coast Guard also actively participates in multiple national and international conferences throughout the year to increase awareness of our program regulations and the issue of ANS introductions. U.S. Coast Guard field offices are also given training and information so that they may provide the most up-to-date information to the crews of commercial vessels when they are inspected.

Another excellent outreach resource is the U.S. Coast Guard Auxiliary, a volunteer group that assists the USCG in non-law enforcement programs. Through the Auxiliary, the Coast Guard is able to utilize and distribute reference materials from other environmental organizations on area specific ANS concerns to the boating public. In addition, the Coast Guard is currently developing an ANS training program for the Auxiliary that will help provide more information to Auxiliary members to educate the boating public.

The Coast Guard is constantly seeking to improve its outreach program to disseminate its message to the maritime sector, and will continue to work to decrease the spread of ANS by ships and recreational vessels.

e-Management for Unwanted Guests: Ontario's Information Management Tools for Invading Species

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Canada recognizes the need for a more collaborative and coordinated approach to managing the data needs in addressing invasive species issues at local, national and international levels. The Ontario Ministry of Natural Resources has embarked on an initiative with NatureServe Canada to develop and implement a robust data management system called Biotics that is able to incorporate different aspects of biodiversity information such as species at risk, natural heritage and invasive species data.

The objectives of the information system are to be the focal point for collecting and providing up-to-date information and thereby facilitating outreach and education, to provide a centralized and coordinated approach to invasive species data management and ensure compatibility with other major sources of invasive species data globally and to aid in advancing methods for the prevention of new introductions, early detection, control and management of these invaders.

An important feature of the database is that it will be coupled with a comprehensive web-accessible user interface called CanTrack. Members of the public will be able to report and view online the geographic distribution and spread of invading species of interest. The applicability of I-Ranks, which is a measure of the invasiveness of non-native species, is also being investigated. I-Ranks are intended to assist in identifying and prioritizing invasive species that require particular attention based on their potential to adversely impact native species biodiversity.

Details of the application will be discussed including information on converting 12 years of aquatic invasive species data into a format that would function in the new Biotics system. This system is already widely used by resource agencies throughout North America, Latin America and the Caribbean to store natural resources information including occurrence of native species, species at risk and other natural heritage information. By incorporating data on invasive species there is great potential for this system to provide resource managers with increased ability to monitor detect and manage aquatic invasive species.

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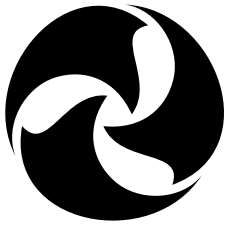
The Institute for Inland Water Management and Waste Water Treatment (RIZA)
will be the host of the



15th International Conference on Aquatic Invasive Species

to be held in Nijmegen, The Netherlands in October 2007.
Information about the conference is available on the ICAIS website www.icais.org/.

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