

11-2015

Dreissenid Mussel Research Priorities Workshop

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Citation Details

Sytsma, Mark D.; Phillips, Stephen; and Counihan, Timothy D., "Dreissenid Mussel Research Priorities Workshop" (2015). *Center for Lakes and Reservoirs Publications and Presentations*. 49.

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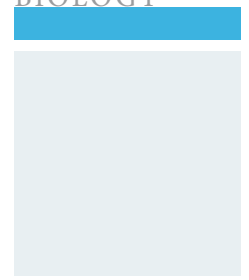
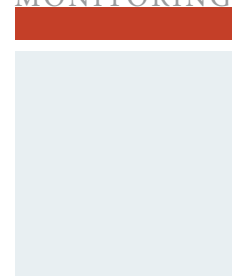
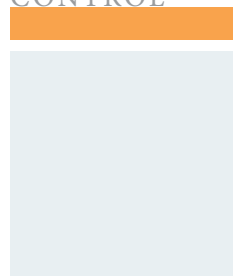
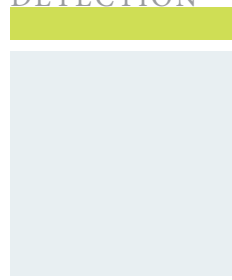
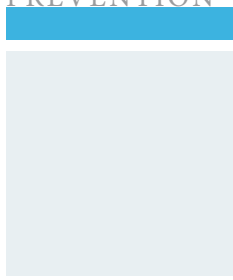
PREVENTION

DETECTION

CONTROL

MONITORING

BIOLOGY



DREISSENID MUSSEL RESEARCH PRIORITIES WORKSHOP

NOVEMBER 2015



Great Northern
LANDSCAPE CONSERVATION COOPERATIVE



Portland State
UNIVERSITY

USGS
science for a changing world



GRAPHIC CREDIT: 100TH MERIDIAN

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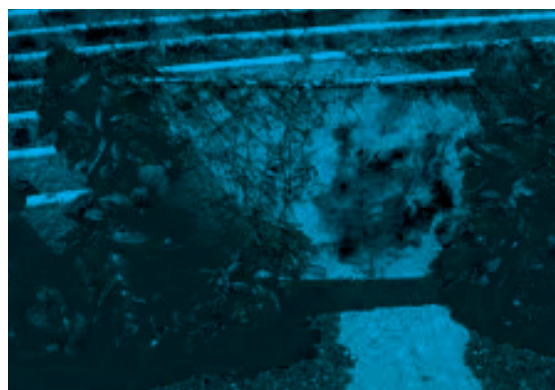


Photo credits: Top photo - USGS; *Clean, Drain, Dry* pamphlet - Alberta; Mussel photo in middle - California Sea Grant; Bottom photo - Bureau of Reclamation.

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ACKNOWLEDGMENTS

The conveners of this workshop wish to thank the Great Northern Landscape Conservation Cooperative for the funding provided to conduct the workshop, Meredith Jordan for her assistance in organizing the workshop, and Creative Resource Strategies, LLC for facilitating the workshop.

EXECUTIVE SUMMARY

Currently, dreissenid mussels have yet to be detected in the northwestern part of the United States and western Canada. Infestation of one of the jurisdictions within the mussel-free Pacific Northwest would likely have significant economic, societal and environmental implications for the entire region. Understanding the biology and environmental tolerances of dreissenid mussels, and effectiveness of various management strategies, is key to prevention.

On November 4-5, 2015, a Dreissenid Mussel Research Priorities Workshop funded by the Great Northern Landscape Conservation Cooperative occurred at Portland State University. The purpose of the workshop was to update research priorities in the 2010 Quagga-Zebra Mussel Action Plan in light of the westward expansion of mussels in the United States and Canada.

A total of 28 experts in mussel biology, ecology, and management attended the workshop. A pre-workshop survey was provided to individuals recognized as experts in their field, including some that were unable to attend the workshop. Workshop attendees reviewed the pre-workshop survey results, the priorities from the 2010 Quagga-Zebra Mussel Action Plan, and recommendations made by presenters at the workshop. Attendees then prioritized research within the categories of prevention, detection, monitoring, management and control. In addition, research on the human dimensions of mussel dispersal and management were identified as critical to successful prevention and response to a mussel introduction.

Given the limited resources that exist to conduct dreissenid research, the entities that participated in the pre-workshop survey and the workshop concur that the recommendations of top tier priorities listed in this report are the highest priority dreissenid research projects that should be funded to advance our understanding of dreissenid prevention, detection, control, monitoring and biology.

The highest priority research questions* identified by workshop attendees included:

Prevention

- Can we manage water bodies to decrease risk of dreissenid establishment and infestation?
- What factors, in addition to calcium, can be used to assess risk of establishment, growth, and reproduction in Pacific Northwest water bodies?
- Can we use road vehicle traffic patterns to target high-risk vessels?
- Can decontamination techniques be aligned with boat manufacturing standards? What tools for increasing the efficacy of decontamination of boats can be developed? Retrofits? New decontamination technologies?
- How long do dreissenids survive out of water under different temperature and humidity regimes?

Detection

- What Quality Assurance/Quality Control protocols are appropriate for veliger sampling and molecular and microscopic analyses?
- What tools can help address the confounding matrix that affects analytical time, effectiveness and cost?
- What areas and habitats of threatened and

Note: There is no implied priority among the five categories; they are listed by category in no specific order.

endangered species are at risk to dreissenid invasions?

- What are the most informative biotic and abiotic factors to use in a risk assessment to determine highest priority areas needing higher frequency of sample collection to detect dreissenids at an early stage?

Control

- What are the acute and chronic effects of control options on non-target species, especially Endangered Species Act (ESA) species found in the Columbia River Basin?
- How successful was each part of eradication attempts (i.e., validation of control success; do we spread while implementing response)?
- Are there ideal timing windows for control options (e.g., reproductive cycle, control combinations)?
- Can gene drive be used to eliminate dreissenid mussels, and is it an ethical control option?
- What host-specific “novel” parasites, or other bio-control agents, can be developed for dreissenid control?

Monitoring

- What are the most cost-effective and efficient population monitoring methods and protocols for dreissenid juveniles/adults/veligers?
- Can we use modeling to direct monitoring (e.g., spatial - regional, i.e., water body selection; within a water body, i.e., depth, longitudinal - and temporal, e.g., seasonality, water temperature)?
- What are the key gaps in our understanding of risk (e.g., gravity models, water quality)?

Biology

- What biotic and abiotic conditions limit distribution, growth and fecundity of dreissenids?
- How do quagga mussel tolerances differ from zebra mussels, how long can dreissenid veligers remain

viable in a variety of temperatures and conditions, what are their physiological tolerances during transport, and what are their optimal reproduction and growth conditions?

- How will dreissenids affect the Columbia River system if climate change model predictions of future water temperatures and flows are the “new normal” in 25–50 years?
- What are the ecological effects of dreissenids in the West?

Human Dimensions

Research questions relating to the human dimensions of mussel introduction and management were not ranked. The scope and quantity of questions posed emphasizes a strong need to invest in research on how human behavior influences spread of mussels and other invasive species.

- What are the most effective “fresh” outreach/education tools/media and/or messages to encourage best practices/change behavior and attitudes to both prevent AIS spread and communicate relevant impacts, and who are the key audiences for these messages? To what extent is this already known? Who is the best audience to reach with this messaging?
- Can dogs help to reduce burnout of inspection with a friendly solution?
- What is the enforcement-level threshold for changing behavior in prevention practices?
- How can we most effectively sell biocontrol/genetic tools as safe?
- How do we keep invasive species messaging “fresh”?
- How do we sell biocontrol/genetic tools as “safe,” given the current debate relative to genetically modified organisms?
- What are the most effective tools to get target audiences to change their behavior?
- What is the enforcement level “threshold” for changing behavior in prevention practices?

- For water bodies targeted with rapid response plans, what public attitude barriers exist within associated communities (for containment and treatment options)?
- How do we identify non-compliant sectors, and how can their behavior be changed?
- How do we bridge the gap between regulatory needs and appropriate legislation?
- How do we close the gap between attitudes and behaviors? Incentives?
- What are the values of general public boaters?
- How do we effectively sell prevention in perpetuity?
- How do we discuss the appropriate potential impacts with different audiences under one umbrella message? Do we need to?
- How do we identify relevant impacts to Pacific Northwest audiences/legislators/agencies?
- How can we improve our ability to coordinate nationally relative to dreissenid detection as well as information sharing across regions, states, and agencies?

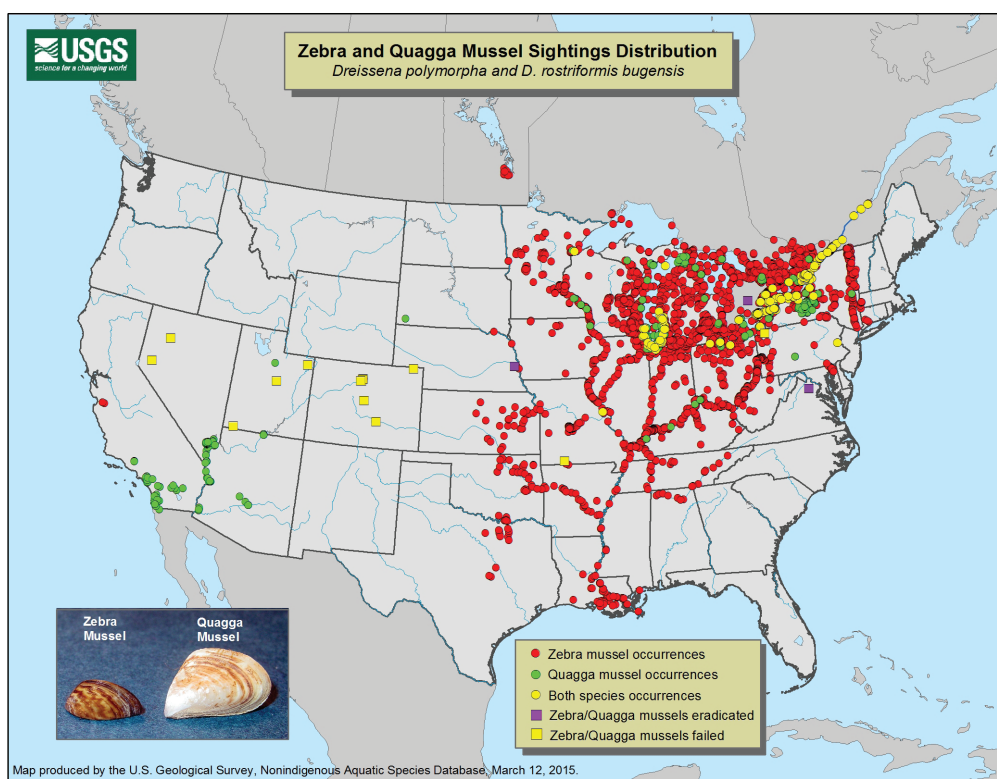


Figure 1. Current distribution of dreissenids in North America. Source: USGS.

INTRODUCTION

Currently, dreissenid mussels have yet to be detected in the northwestern part of the United States and Canada. Infestation of one of the jurisdictions within the mussel-free Pacific Northwest would likely have significant detrimental economic, societal and environmental effects. Understanding the biology and environmental tolerances of dreissenid mussels, and effectiveness of various management strategies, is key to prevention, monitoring, and response to an invasion of the region.

Various large-scale, jurisdictional-based and trans-boundary collaborative management initiatives address dreissenid mussels in the Pacific Northwest. Funding has focused on management with current methodologies, e.g., risk assessments and surveillance, with little effort on research that could enhance management and prevention. Understanding landscape-scale stressors, species-specific habitat requirements (e.g., quagga mussel and water temperature requirements) and the development of early detection and rapid response methodologies, requires additional research to effectively address the potential of mussel introductions to the remaining mussel-free areas.

On November 4-5, 2015, the Aquatic Bioinvasion Research and Policy Institute and the Center for Lakes and Reservoirs at Portland State University, the US Geological Survey, and the Pacific States Marine Fisheries Commission, convened a Dreissenid Mussel Research Priorities Workshop funded by the Great Northern Landscape Conservation Cooperative. The purpose of the workshop was to review dreissenid research priorities in the *2010 Quagga-Zebra Mussel Action Plan for Western U.S. Waters*, reassess those priorities, incorporate new information and emerging trends, and develop priorities to strategically focus research efforts on zebra and quagga mussels in the Pacific Northwest and ensure that future research is focused on the highest priorities. It is important to note that there is some repetition among dreissenid research priority categories (e.g., prevention, detection, control, monitoring, and biology).

The workshop was held at Portland State University.

Workshop participants with research experience in dreissenid mussel biology and management were identified by a literature review. State and federal agency managers were also invited to the workshop to ensure relevancy and practicality of the workshop outcomes. A total of 28 experts (see sidebar) in mussel biology, ecology, and management attended the workshop.

WORKSHOP ATTENDEES

Chris Berger, Portland State University
 Rick Boatner, Oregon Dept. Fish and Wildlife
 Steve Bollens, Washington State University
 Tim Counihan, US Geological Survey
 Lisa DeBruyckere, Creative Resource Strategies
 Robyn Draheim, US Fish and Wildlife Service
 Jackson Gross, Smith-Root
 Paul Heimowitz, US Fish and Wildlife Service
 Denise Hosler, Bureau of Reclamation
 Chris Jerde, University of Nevada - Reno
 Kimberly Johnson, Bonneville Power Administration
 Lisa Jones, McGill University
 Meredith Jordan, Portland State University
 Bob McMahon, University of Texas - Austin
 Christine Moffitt, University of Idaho
 Dan Molloy, State University of New York
 Bryan Moore, National Park Service
 Stephen Phillips, Pacific States Marine Fisheries Commission
 Allen Pleus, Washington Dept. Fish and Wildlife
 Gretchen Rollwagen-Bollens, Washington State University
 Ben Smith, National Park Service
 Kelly Stockton, KASF Consulting
 Angela Strecker, Portland State University
 Mark Sytsma, Portland State University
 Theresa Thom, National Park Service
 Steve Wells, Portland State University
 Leonard Willett, Bureau of Reclamation
 David Wong, Massachusetts Dept. Environmental Protection

PRE-WORKSHOP SURVEY RESULTS

Prior to the November 2015 workshop, experts in dreissenid management, control, biology, prevention and research were contacted to complete a short survey. The survey was used to incorporate suggestions from a diversity of experts, some of whom could not attend the workshop. In addition, survey results were used to assess initial priorities for further discussion at the workshop.

The survey was developed to review the high priority development and research gaps in the 2010 Quagga-Zebra Mussel Action Plan and rank them in terms of their priority in 2015. The following categories were ranked from “lowest” to “highest” priority by 13 survey respondents:

Prevention and Spread (PR)

- Decontamination efficacy
- Physiological tolerances
- Genetic fingerprinting

Early Detection and Monitoring (ED)

- Early detection methodologies
- Research for PCR assays

Rapid Response (RR)

- Fast/reliable testing for detection
- Proven methods for watercraft decontamination

Control of Established Populations (C)

- Research biological control
- Host-specific parasites
- Eco-friendly chemical control

Outreach and Education (O)

- Social science research

Of the 11 categories, survey respondents gave five categories combined rankings of nine or more in the “highest” or “higher categories” (Table 1):

- PR - Decontamination efficacy (10)
- ED - Early detection methodologies (10)
- RR - Fast/reliable testing for detection (9)
- RR - Proven methods for watercraft decontamination (10)
- O - Social science research (11)

Second tier categories (those with combined “highest” or “higher” rankings of six or seven points) included:

- PR - Physiological tolerances (7)
- ED - Research for Polymerase Chain Reaction (PCR) Assays (7)
- C - Research biological control (6)
- C - Eco-friendly chemical control (7)

Third tier categories (those with the least amount of “highest” or “higher” rankings):

- PR - Genetic fingerprinting (2)
- C - Host-specific parasites (2)

In addition to ranking the categories listed above, survey respondents were asked to provide up to three high-priority research questions that need to be addressed in each of the following categories: research, prevention, detection, monitoring, and control. The results were listed by their respective categories as starting places for workshop attendees to have discussion about priorities.

Zebra mussels on native mussels.
Photo credit: Randy Westbrooks, USGS.

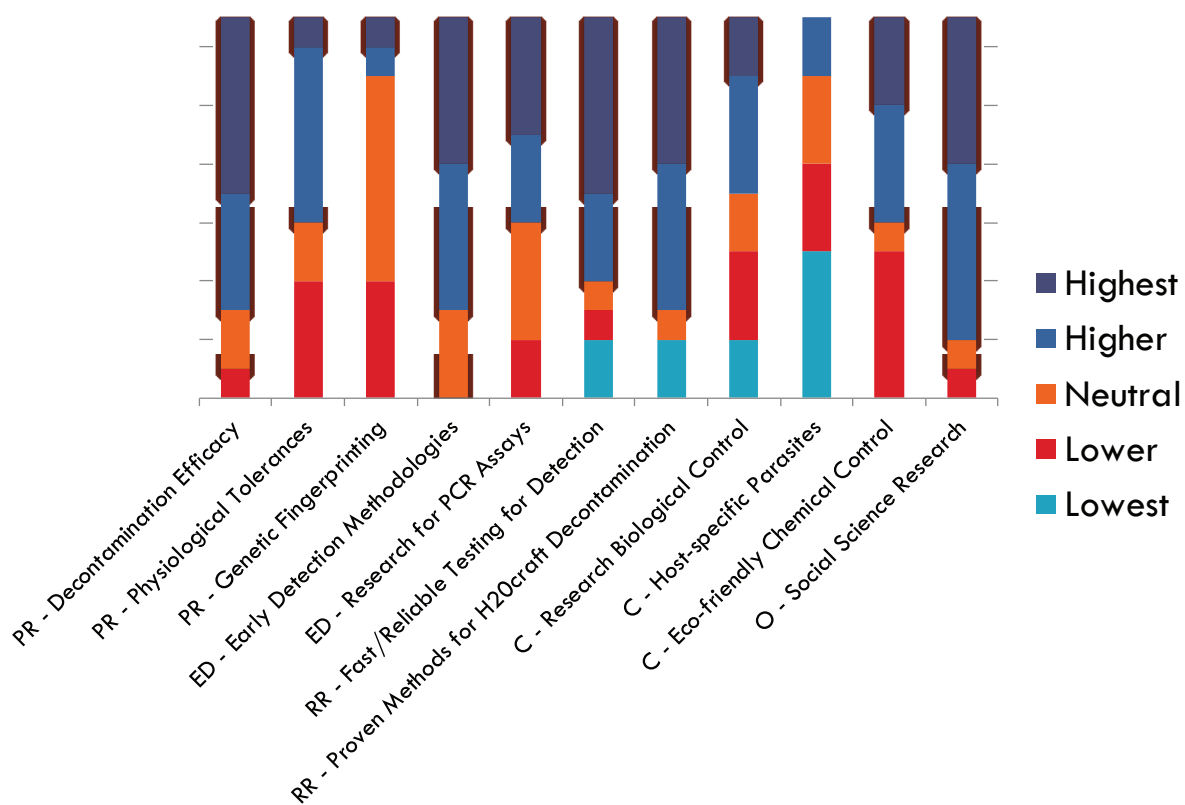


Table 1. Rankings of 2010 Quagga-Zebra Mussel Action Plan Research Priorities in advance of 2015 workshop.

WORKSHOP METHODOLOGY

The initial results of the survey were presented to workshop participants, followed by a listing and discussion of the five research priorities in the Quagga-Zebra Mussel 2010 Action Plan:

- Determine physiological tolerances.
- Develop a method to track dispersal via genetic fingerprints.
- Develop alternative decontamination methods.
- Develop biological control methods.
- Develop eco-friendly chemical control methods.

A series of presentations were made (Appendix A - Workshop agenda) in which the speakers identified a set of possible research topics associated with detection, control, prevention, monitoring, and biology. Speaker suggestions were added to the list of priority topics from the pre-workshop survey. Then workshop attendees were asked to review all recommendations from the pre-workshop survey and presentation speakers, and compile, modify, edit, and add to these lists to create comprehensive lists of research topics by category. Attendees were also asked to critically analyze each recommendation, assessing whether or not the recommendation was a true research project (e.g., one that requires development or collection of new knowledge), and if not, to reword the recommendation in such a way that it could be framed as a meaningful research question.

The next step was to ask workshop attendees to prioritize within each category. The final step included prioritizing across all categories to create one tiered prioritized list of research needed to advance our understanding of dreissenid prevention, detection, control, monitoring, and biology.

Prioritization was done using the “dot-voting” method. Appendix II includes a complete listing of the research projects by category (i.e., prevention, control, biology, etc.) as well as number of votes received during the workshop. Following the workshop, some of the research questions were edited for clarity and to reduce duplication.

“

Although the invasion continues, it must be remembered that the zebra mussel is but one in a long line of aquatic invaders (the Asian clam, *Corbicula fluminea*, and the sea lamprey, *Petromyzon marinus*, being two more historic cases in North America freshwaters) that will continue to arrive if the lessons learned from this invasion are not well applied.

~ Ladd Erik Johnson,
Universite Laval, Quebec, Canada



Dreissenid sample processing and analysis at the Great Lakes Environmental Research Laboratory. Photo credit: GLERL.

RESULTS

Workshop participants ranked the following research priorities (the number in parentheses after the question indicates the number of “votes” the research question received by workshop attendees):

PREVENTION

- Can we manage water bodies to decrease risk of dreissenid establishment and infestation? (27)
- What factors, in addition to calcium, can be used to assess risk of establishment, growth, and reproduction in Pacific Northwest water bodies? (25)
- Can we use road vehicle traffic patterns to target high-risk vessels? (20)
- Can decontamination techniques be aligned with boat manufacturing standards? What tools for increasing the efficacy of decontamination of boats can be developed? Retrofits? New decontamination technologies? (10)
- How long do quagga mussels survive out of water under different temperature and humidity regimes? (10)
- What is the cost-benefit breaking point with increased enforcement on highways? (5)
- What are the vectors that pose the highest risk for introducing dreissenid mussels to uninfected waterways (e.g., types of motors, types of watercraft, construction equipment, etc.), and what are the best/most effective ways to reduce risk/prevent introduction of dreissenid mussels into currently uncontaminated areas? (4)
- Are dogs effective in detecting all mussel life stages? (2)
- What flowing water conditions limit settlement and growth of mussels? Can we link that data to the spread of mussels? (1)

DETECTION

- What Quality Assurance/Quality Control protocols are appropriate for veliger sampling and molecular and microscopic analyses? (20)
- What tools can help address the factors that affect analytical time, effectiveness and cost? (13)
- What areas and habitats of threatened and endangered species are at risk to dreissenid invasions? (9)
- What are the most appropriate biotic and abiotic factors to use in a risk assessment to determine highest priority areas needing higher frequency of sample collection to detect dreissenids at an early stage? (9)
- How effective are broad-taxa passive environmental deoxyribonucleic acid (eDNA) surveys in detecting dreissenids in infested waters? (6)
- How effective is using eDNA from ethanol as a pre-screening for aquatic invasive species? (6)
- What is the correlation between plankton and eDNA sampling strategy by covariates (e.g., water volume, surface area, etc)? (6)
- What variables affect outcomes of standard dreissenid detection methods? (5)
- Can you pinpoint eDNA source? (5)
- How do past/present dreissenid detection results relate to known current dreissenid populations? (4)
- How long can dreissenid DNA persist in various aquatic conditions? (4)
- Are there any chemical signals (i.e., settlement pheromones) or cues for early detection? (4)

RESULTS

CONTROL

- What are the acute and chronic impacts of chemical and other control options on non-target species, especially Endangered Species Act (ESA) species found in the Columbia River Basin? (16)
- What are the acute and chronic impacts of control options on non-target species, especially Endangered Species Act (ESA) species found in the Columbia River Basin? (16)
- How successful was each part of eradication attempts (i.e., validation of control success; do we spread while implementing response)? (13)
- Are there ideal timing windows for control options (e.g., reproductive cycle, control combinations)? (11)
- Can gene drive be used to eliminate dreissenid mussels, and is it an ethical control option? (11)
- What host-specific “novel” parasites, or other bio-control agents, can be developed for dreissenid control? (13)
- What new boat construction designs can be developed and implemented for long-term mitigation of impacts? (8)
- What infrastructure/physical containment is needed to isolate early detection populations of dreissenids while planning a response or staging? (6)
- What are the biological and sociological thresholds for eradication, i.e., when is it no longer feasible to attempt control? (6)
- What control methods are cost-effective, environmentally friendly, and convenient to use in both open water and closed system treatments? (6)
- What are appropriate effectiveness monitoring protocols for control and eradication? (3)
- How effective are multiple simultaneous control treatments (e.g., Zequanox® and potash)? (3)
- Have dreissenids developed resistance to control products? (2)

MONITORING

- What are the most cost-effective and efficient population monitoring methods and protocols for dreissenid juveniles/adults/veligers? (97)
- Can we use modeling to direct monitoring (e.g., spatial - regional, i.e., water body selection; within a water body, i.e., depth, longitudinal - and temporal, e.g., seasonality, water temperature)? (13)
- What are the key gaps in our understanding of risk (e.g., gravity models, water quality)? (11)
- What constitutes effective veliger/adult mussel monitoring using trained dogs? (6)
- What is the most effective molecular technique to monitor the size of a dreissenid population? (5)
- How effective is citizen science in monitoring for dreissenids? (4)
- What is the correlation of eDNA sample size to plankton tows/substrate sampling methods? (3)

RESULTS

BIOLOGY

- What biotic and abiotic conditions limit distribution, growth and fecundity of dreissenids? (20)
- How do quagga mussel tolerances differ from zebra mussels, how long can dreissenid veligers remain viable in a variety of temperatures and conditions, what are their physiological tolerances during transport, and what are their optimal reproduction and growth conditions? (17)
- What controls distribution of dreissenids? (14)
- How will climate change alter dreissenid effects on the Columbia River system under a range of water temperature and flow regimes? (11)
- What are the actual ecological impacts of dreissenids in the West? (9)
- Why are some dreissenid populations in Europe and North America subject to long-term population collapse? (7)
- Do pheromones, chemotoxins, and phototoxins influence behavior of dreissenid veligers and adults? (6)
- How do other invasions enhance or inhibit the ability for dreissenid introduction and establishment? (5)
- What are the food preferences and filtration rates, and is there bioaccumulation of heavy metals and other toxins in dreissenid tissue? (5)
- Can quagga mussels outcompete zebra mussels in oligotrophic water based on how they feed on bacteria? (4)
- What is a quick and low-cost method to determine in the field if a closed dreissenid is still alive? (4)
- What are the microhabitat tolerances (e.g., calcium, water quality) of quagga and zebra mussels? (2)
- Does establishment of dreissenids require a near simultaneous introduction of a large number of individuals? (2)
- How does genetic diversity of dreissenids in North America compare to European populations? (2)
- What are the likely modes of translocation of juvenile and adult dreissenids? (2)
- How fast do physiological tolerances evolve in dreissenids? (2)

TOP TIER PRIORITIES

The list below is the recommended list of “top tier” priority research projects. Top-tier priorities were defined as those questions within the categories of prevention, detection, control, monitoring, and biology that were ranked of greater importance than other questions based on the number of votes received.

Prevention

- Can we manage water bodies to decrease risk of dreissenid establishment and infestation? (27)
- What factors, in addition to calcium, can be used to assess risk of establishment, growth, and reproduction in Pacific Northwest water bodies? (25)
- Can we use traffic patterns to target high-risk vessels? (20)
- Can decontamination techniques be aligned with boat manufacturing standards? What tools for increasing the efficacy of decontamination of boats can be developed? Retrofits? New decontamination technologies? (10)
- How long do dreissenids survive out of water under different temperature and humidity regimes? (10)

Detection

- What Quality Assurance/Quality Control protocols are appropriate for veliger sampling and molecular and microscopic analyses? (20)
- What tools can help address the confounding matrix that affects analytical time, effectiveness and cost? (13)

- What areas and habitats of threatened and endangered species are at risk to dreissenid invasions? (9)
- What are the most informative biotic and abiotic factors to use in a risk assessment to determine highest priority areas needing higher frequency of sample collection to detect dreissenids at an early stage? (9)

Control

- What are the acute and chronic effects of control options on non-target species, especially Endangered Species Act (ESA) species found in the Columbia River Basin? (16)
- Are there ideal timing windows for dreissenid control options (e.g., reproductive cycle, control combinations)? (11)
- Can gene drive¹ be used to eliminate dreissenid mussels, and is it an ethical control option? (11)
- What host-specific “novel” parasites, or other bio-control agents, can be developed for dreissenid control? (13)

¹Gene drive is the practice of stimulating biased inheritance of particular genes to alter entire populations.

Monitoring

- What are the most cost-effective and efficient population monitoring methods and protocols for dreissenid juveniles/adults/veligers? (97)
- Can we use modeling to direct monitoring (e.g., spatial - regional, i.e., water body selection; within a water body, i.e., depth, longitudinal - and temporal, e.g., seasonality, water temperature)? (13)
- What are the key gaps in our understanding of risk (e.g., gravity models, water quality)? (11)

Biology

- What biotic and abiotic conditions limit distribution, growth and fecundity of dreissenids? (34)
- Do zebra and quagga mussels differ in environmental tolerances and optimal reproduction and growth conditions? (11)
- How will dreissenids affect the Columbia River system if climate change model predictions of future water temperatures and flows are the “new normal” in 25–50 years? (11)
- What are the actual ecological impacts of dreissenids in the West? (9)

HUMAN DIMENSIONS

Although research questions relating to the human dimensions of mussel introduction and management were not ranked, the scope and quantity of questions posed emphasizes a strong need to invest in research on how human behavior influences spread of mussels and other invasive species.

- What are the most effective “fresh” outreach/education tools/media and/or messages to encourage best practices/change behavior and attitudes to both prevent AIS spread and communicate relevant impacts, and who are the key audiences for these messages? To what extent is this already known? Who is the best audience to reach with this messaging?
- Can dogs help to reduce burnout of inspection with a friendly solution?
- What is the enforcement-level threshold for changing behavior in prevention practices?
- How can we most effectively sell biocontrol/genetic tools as safe?
- How do we keep invasive species messaging “fresh”?
- How do we sell biocontrol/genetic tools as “safe,” given the current debate relative to genetically modified organisms?
- What are the most effective tools to get target audiences to change their behavior?
- What is the enforcement level “threshold” for changing behavior in prevention practices?
- For water bodies targeted with rapid response plans, what public attitude barriers exist within associated communities (for containment and treatment options)?
- How do we identify non-compliant sectors, and how can their behavior be changed?
- How do we bridge the gap between regulatory needs and appropriate legislation?
- How do we close the gap between attitudes and behaviors? Incentives?
- What are the values of general public boaters?
- How do we effectively sell prevention in perpetuity?
- How do we discuss the appropriate potential impacts with different audiences under one umbrella message? Do we need to?
- How do we identify relevant impacts to Pacific Northwest audiences/legislators/agencies?
- How can we improve our ability to coordinate nationally relative to dreissenid detection as well as information sharing across regions, states, and agencies?

The scope and scale of interest in human dimensions research associated with invasives warrants additional attention and funding to ensure investments made in outreach and education align with target audience needs and values.

APPENDICES

Appendix I. Workshop Agenda

Center for Lakes and Reservoirs
 Aquatic Bioinvasion Research and Policy Institute
 Portland State University

DREISSENID MUSSEL RESEARCH PRIORITIES WORKSHOP

November 4, 2015, 1:00PM–5:00PM

November 5, 2015, 8AM–NOON

University Place Hotel, Coos Bay Room
 310 SW Lincoln Street
 Portland, Oregon 97201

Goal: Review and reassess dreissenid research priorities to help ensure future research is focused on the highest priorities

NOVEMBER 4, 2015

1:00 PM – 1:10 PM	WELCOME, INTRODUCTIONS AND REVIEW OF AGENDA
1:10 PM – 1:40 PM	STATE OF THE NORTHWEST AND THE MANAGEMENT CONUNDRUM - DEALING WITH DREISSENIDS A brief overview of the mussel prevention in the Pacific Northwest, and an exploration of the economic, environmental and social impacts of dreissenids, including prioritizing those impacts of greatest concern to the Pacific Northwest (e.g., hydropower, irrigation) – Stephen Phillips
1:40 PM – 2:25 PM	MUSSEL BIOLOGY 101 The reproductive biology, thermal tolerance, chemical tolerance, and other aspects of mussel biology will be summarized – what we know, what we don't know, and why we need to know it – Robert McMahon
2:25 PM – 3:00 PM	MONITORING DREISSENIDS The most common protocols for monitoring dreissenids will be discussed, including identifying research needs associated with monitoring efforts – Tim Counihan
3:00 PM – 3:15 PM	BREAK

3:15 PM – 4:00 PM	<p>DETECTING DREISSENID ADULTS AND VELIGERS – TECHNIQUES AND GAPS</p> <p>A suite of existing and emerging methods of detecting dreissenids will be discussed, including a description of pros and cons for each method as well as identification of new and improved methods and associated infrastructure needed to detect dreissenids and address specific threats</p> <ul style="list-style-type: none"> • Microscopy – Steve Wells • Flow cam – Gretchen Rollwagen-Bollens • eDNA – Chris Jerde
4:00PM – 4:45PM	<p>CONTROLLING DREISSENIDS 101 & RESEARCH RECOMMENDATIONS</p> <p>Current chemical, physical, and biological tools available to control dreissenids will be summarized, and research priorities to address spread and prevention efforts discussed, including a bold, new, economical, eco-friendly paradigm for long-term control of dreissenids throughout entire water bodies – Dan Molloy</p>
4:45PM – 5:00PM	<p>SUMMARY, WRAP-UP AND REVIEW OF TOMORROW’S AGENDA</p>
NOVEMBER 5, 2015	
8:00 AM – 8:05 AM	<p>WELCOME, INTRODUCTIONS AND REVIEW OF AGENDA</p>
8:05 AM – 9:00 AM	<p>SPEAKER PANEL DISCUSSION AND REVISITING QZAP 2010 RESEARCH PRIORITIES</p>
9:00 AM – 11:30 AM	<p>PRIORITIZING DREISSENID RESEARCH – SURVEY RESULTS AND MAKING STRATEGIC INVESTMENTS WITHIN EACH CATEGORY</p> <p>Workshop attendees will work in groups to identify and prioritize research needed in dreissenid biology, detection, prevention, monitoring, and control efforts</p>
11:30 AM –12:30 PM	<p>LUNCH BREAK</p>
12:30 PM – 1:50 PM	<p>PRIORITIZING RESEARCH ACROSS DISCIPLINES – IDENTIFYING THE HIGHEST PRIORITY RESEARCH NEEDS AMONG BIOLOGY, DETECTION, PREVENTION, MONITORING, AND CONTROL</p> <p>The results of the work groups will be summarized and workshop attendees will prioritize research among biology, detection, prevention, monitoring, and control categories to establish one list of the highest priority dreissenid research needs</p>
1:50 PM – 2:00 PM	<p>SUMMARY AND KEY NEXT STEPS</p>
2:00 PM	<p>ADJOURN</p>

Appendix II. Research questions posed during the November 2015 workshop as well as through the pre-workshop survey.

(Note: In a few instances in which the wording of a research project was similar to another, the proposed research projects were combined. Research project with no “N=” in parentheses were projects that received no votes during the workshop).

Prevention:

- Can we manage water bodies to decrease risk of establishment and infestations? (N=27)
- Do high risk boats move differently/in different patterns from low risk/day use, and how can we use traffic patterns to target high risk vessels? (N=20)
- What factors are most effective to use with risk assessment (beyond calcium) to evaluate risk of invasion or establishment? (N=15)
- What waterways are currently uninfected by dreissenid mussels? What factors influence risk of establishment? (N=10)
- Can we align decontamination techniques with boat manufacturing standards? What tools for increasing the efficacy of decontamination of boats can be developed? Retrofits? New decontamination technologies? (N=10)
- How long do dreissenids survive out of water under different temperature and humidity regimes (efficacy of boat wrapping)? (N=10)
- Where is the cost-benefit breaking point with increased enforcement on highways? (N=5)
- What are the vectors that pose the highest risk for introducing dreissenid mussels to uninfected waterways (types of motors, types of watercraft, construction equipment, etc.), and what are the best/most effective ways to reduce risk/prevent introduction of dreissenid mussels into currently uncontaminated areas? (N=4)
- What is the efficacy of dogs for all zebra/quagga mussel life stages? (N=2)
- Is there real, conclusive data on stream and canal survivability? Can we link that data to the spread of mussels? (N=1) Can we compile up-to-date cutting

edge information on detection tools and their pros/cons for use by managers in developing strategic monitoring for ED?

- What is the detection limit?
- How can early detection be refined to actually predict adult or settlement?
- What separation techniques would allow for isolation of veligers from inorganic particles and other organisms

Detection:

- What is the appropriate Quality Assurance/Quality Control for sampling and analysis of eDNA and lab accreditation? (N=20)
- What is the best way to maximize sampling effort to detect very small populations or early infestations for dreissenid adults/juveniles/veligers; various methods (e.g., scuba, Polymerase Chain Reaction (PCR), etc.)? (N=16)
- What tools can help address the factors that affect analytical time, effectiveness and cost? (N=13)
- What areas are at risk to invasives and potential habitats of threatened and endangered species? (N=9)
- What are the most appropriate biotic and abiotic factors to use in a risk assessment to determine highest priority areas needing higher frequency of sample collection to detect dreissenids at an early stage? (N=9)
- How effective are broad-taxa passive eDNA surveys in detecting dreissenids in infested waters? (N=6)
- How effective is using eDNA from ethanol as a pre-screening for AIS? (N=6)
- What is the correlation between plankton and eDNA sampling strategy by covariates (e.g., water volume, surface area, etc.)? (N=6)
- What variables affect outcomes of standard dreissenid detection methods? (N=5)
- Can you pinpoint eDNA source? (N=5)
- How do dreissenid detection results (past and present) relate to known current dreissenid populations? (N=4)

- How long can dreissenid DNA persist in various aquatic conditions? (N=4)
- Are there any chemical signals (i.e., settlement pheromones) or cues for early detection? (N=4)
- What is the most effective sampling frequency for dreissenids?
- What constitutes positive detection for dreissenids?
- What constitutes a viable population?
- How can we best resolve issues with Polymerase Chain Reaction (PCR) methodology, reproducible results, and differing limits of detection?
- Are there dreissenid settlement pheromones or cues?
- What are some effectiveness monitoring recommendations for control and eradication efforts? (N=3)
- How effective are multiple simultaneous treatments (e.g., Zequanox® and potash)? (N=3)
- Have dreissenid mussels developed resistance to control products? (N=2)
- What is the least toxic treatment for closed system eradication of dreissenid mussels? (N=1)
- What environmentally friendly artificial products exist to control mussels, and what eco-friendly chemical controls can be developed? (N=1)
- What are the most effective materials or coatings to prevent dreissenid mussel adhesion to infrastructure, and frequency of application needed?

Control

- What are the acute and chronic impacts of chemical control and other control options on non-target species, especially Endangered Species Act species found in the Columbia River Basin? (N=16)
- Are there ideal timing windows for dreissenid control options that would increase efficacy (e.g., reproductive cycle, control combinations to increase efficacy)? (N=11)
- Can gene drive be effective and ethical? (N=11)
- What host-specific “novel” parasites can be developed for dreissenid control? (N=10)
- What new boat construction designs can be developed and implemented for long-term control? (N= 8)
- What infrastructure/physical containment is needed to isolate early detection populations of dreissenids while planning response or staging? (N=6)
- What are the biological and sociological thresholds for eradication, i.e., when do we give up? (N=6)
- What control methods are cost effective, environmentally friendly, and convenient to use? (N=4)?
- What is an effective biological control method for dreissenids that is host-specific? (N=3)
- What is the effectiveness of current best management practices and provide recommendations for updated best management practices and standard operating procedures?
- What are the pH and temperature effects on efficacy of available molluscicides?

Monitoring

- What are the most cost-effective and efficient population monitoring methods and protocols for dreissenid juveniles/adults and veligers and how can they be allocated over space and time (eDNA, plankton, shoreline walks, substrate monitoring, etc.)? (N=44)
- How can we efficiently allocate dreissenid monitoring sampling efforts over space and time (e.g., by tool - eDNA, plankton, shoreline, substrate)? (N=22)
- How many plankton samples need to be collected to effectively monitor for the presence of dreissenids, and does this change for different water bodies? (N=15)
- Can we use modeling to direct monitoring (e.g., spatial - regional, i.e., water body selection; within a water body, i.e., depth, longitudinal - and temporal, e.g. seasonality, water temperature)? (N=13)
- What are the key gaps in our understanding of risk (e.g., gravity models, water quality)? (N=11)

- What constitutes effective veliger/adult mussel monitoring using trained dogs? (N=6)
- What is the most effective molecular technique to monitor the size of a dreissenid population? (N=5)
- How effective is citizen science in monitoring for dreissenids? (N=4)
- What is the correlation of eDNA sample size to plankton tows/substrate sampling methods? (N=3)
- What are the most effective state monitoring programs for both adult mussels and veligers, and how do these programs compare to the recommended standardized monitoring protocol for veligers and adults to inform population assessments, including seasonality, frequency of sampling?
- What are the key gaps in current monitoring programs at a regional scale?
- Can we compile a comprehensive list of protocols and priorities to develop a regional monitoring plan for early detection (e.g., when and where to sample, quality assurance/quality control for collection/processing, risk identification and targeting)?
- What are the key elements of an early detection monitoring design?
- How do other invasions enhance or inhibit the ability for dreissenid introduction and establishment? (N=5)
- What are the food preferences (selective feeding on zooplankton?), filtration rates, and bioaccumulation of heavy metals and other toxins in mussel tissue? (N=5)
- How will projected climate change affect dreissenid biology in North America? (N=4)
- Can quagga mussels outcompete zebra mussels in oligotrophic water based on how they feed on bacteria? (N=4)
- What is a quick and low-cost method to determine in the field if a closed dreissenid is still alive? (N=4)
- How long can veligers stay viable, in various temperatures, and conditions? Physiological tolerances during transport? (N=3)
- How do quagga mussel tolerances differ from zebra mussels? (N=3)
- In the event of an introduction, are there mechanical controls that can eradicate prior to an established population? (N=2)
- Are there microhabitat calcium and water quality tolerances we need to be concerned about (e.g., ocean acidification, bivalve research)? (N=2)
- Does invasion require a near simultaneous introduction of a large number of individuals? (N=2)

Biology

- What controls distribution of dreissenids? (N=14)
- What are the differences in responses to environmental factors between zebra and quagga mussels? (N=11)
- What biotic and abiotic factors are critical for dreissenid reproduction and fecundity? (N=11)
- What are the actual ecological impacts of dreissenids in the West proving to be? (N=9)
- What biotic and abiotic factors influence bioenergetics of quagga and zebra mussels? (N=9)
- How will climate change alter dreissenid effects on the Columbia River system under a range of water temperature and flow regimes? (N=7)
- Why are some dreissenid populations in Europe and North America subject to long-term population collapse? (N=7)
- Do pheromones, chemotoxins, and phototoxins influence behavior of veligers and adults? (N=6)
- How does genetic diversity of dreissenids in North America compare to European populations? (N=2)
- How often and what are the likely models of translocation of juveniles/adults? (N=2)
- How fast do physiological tolerances evolve in dreissenids? (N=1)
- What are the differences in responses to environmental factors between zebra and quagga mussels?
- What are the niche challenges for survival in waters of the western U.S.?
- What are the factors that have made the spread slower than anticipated?
- Do mussels in the West show settlement preferences?
- What are differences in thermal tolerances between adults/veligers and growth rates and life spans across North America?

- How does thermal tolerance evolve in isolated water bodies?
- Can zebra mussels better inhabit periodically hypoxic zones?
- Are zebra mussels more tolerant of immersion than quagga mussels?
- What is the minimum temperature for spawning and veliger survival in populations recently established in the West?



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