Recommendations for Dreissenid Mussel Prevention, Management, Research, Coordination, and Outreach for the Columbia River Basin

A Roadmap to Make Strategic Investments in
Federal Columbia River Power System and Technology Innovation Programs

Appendix

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I. EXECUTIVE SUMMARY

Aquatic Invasive Species (AIS), and particularly dreissenid mussels, have been receiving increased attention from decision makers and natural resource agencies in recent years because of their economic, environmental, and social threats. Funding requests for needed AIS prevention has outstripped both state and federal agency budget capabilities.

Because limited funding is available in the current budget climate to address priority AIS issues, a coordinated strategy (roadmap) of where state, federal tribal and local water resource managers invest its resources is needed. This document describes key thematic areas associated with AIS efforts: prevention, management, mitigation/control, research, monitoring, interjurisdictional coordination, and education and outreach. Within each thematic area or section, a set of recommendations was made to advance the key strategies.

A.1 Prevention (Watercraft Inspection)

1. **Perimeter watercraft inspection stations:** Interception of mussel-contaminated boats when they enter the mussel-free region of the Pacific Northwest is most effectively and efficiently conducted at the perimeter of the region. At present, states in the Pacific Northwest conduct boat inspections within (or at) their borders. These inspection stations have proven effective, intercepting hundreds of contaminated watercraft in the past several years, but there are gaps in coverage that need closing. Additionally, development of processes and policies that permit states to function as a unit by pooling resources to jointly fund and prioritize locating regional border inspection stations could allow these stations to remain open longer, intercept more boats and more effectively protect the region from mussel introduction.

2. **Decontaminate boats leaving infested water bodies:** Continue to work with federal partners (i.e., Department of Interior) to increase decontamination efficiencies at federally managed water bodies (e.g., Lake Mead).

3. **Regional watercraft electronic database:** Continue development of a western regional shared watercraft inspection and decontamination electronic database that will assure real-time communication about movements and inspection of high risk boats in West.

4. **Reciprocity:** Continue to implement cooperative/reciprocal agreements between jurisdictions conducting watercraft inspections and decontaminations.

5. **Regional AIS passport:** Continue to pursue the implementation of a regional AIS Passport system.

A.2 Prevention (Watercraft Decontamination)

1. Seek to develop additional technologies for watercraft decontamination that are effective in killing and removing dreissenid mussels.

2. Work with watercraft/recreational industry partners in the development of watercraft designs that reduce the threat of spreading AIS.

B.1 Management (Dreissenid Mussel Eradication)

1. Pesticide Registration—Refine the list of registered Section 3 pesticides for Oregon and Washington, designating which would most likely be used to control an introduction of invasive mussels.

2. Take steps to ensure the most likely products to be used for invasive mussel control are listed as Section 3 pesticides in each state.

3. Section 18 of FIFRA—Explore opportunities to respond to an introduction of invasive mussels by developing the components of a Section 18 (which would authorize an unregistered use of a pesticide for a limited time if EPA determines emergency conditions exist) that can be applied for regionally.

4. Begin taking steps to conduct a programmatic consultation for the region by working with the National Oceanic and Atmospheric Administration/National Marine Fisheries Service (NOAA/NMFS) and the USFWS to assimilate existing information and identify key information gaps needed to inform its development.

B.2 Management (Rapid Response Preparedness)

1. The states of Washington and Montana need to complete their dreissenid rapid response plans.

2. The State of Idaho needs to update its Contingency Plan based on information developed from the December 11, 2013 Oregon-Washington Rapid Response Working Group meeting.

C. 1 Vulnerability Assessments

1. **CRB hydropower vulnerability assessments:** Complete vulnerability assessments at hydropower projects in the Columbia River Basin.

C.2 Mitigation

1. **Mitigation strategy options:** Further develop mitigation strategy options (both physical and chemical) including cost estimates for hydropower and fish facilities.

2. **Environmental permitting:** Initiate environmental permitting process (i.e., National Environmental Policy Act (NEPA), Endangered Species Act (ESA), Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)) with appropriate regulators for use of cost effective mitigation technologies identified above at FCRPS hydropower and fish facilities.

D. Research

1. **Assess ability of Columbia River tributaries to support dreissenids:** Bolster knowledge of risk of establishment by improving understanding of the ability of primary and secondary tributaries to the mainstem Columbia River to support quagga and zebra mussels.

2. **Invasive mussel larval development rates:** Calculate the expected time required for dreissenid veligers to travel from the upper to lower portions of the CRB.

3. **Assess potential for dreissenid survival in CRB:** Continue assessing potential for long-term reproductive success, specifically the potential for successful dreissenid spawning and juvenile survival in the CRB.

4. **Predict dreissenid mussel levels in CRB:** Collect additional calcium and pH data in various parts of the Columbia watershed to better predict dreissenid mussel levels (densities) in this environment.

5. **Assess potential for reservoir management strategies:** Investigate the possibility of reservoir management strategies that could be used for the control of established dreissenid populations.

E. Monitoring

1. **Sample high risk water bodies:** Continue evaluating and prioritizing dreissenid monitoring activities to ensure highest risk water bodies are receiving the majority of sampling effort.

2. **Determine appropriate level of water sampling in CRB:** Determine the current volume of water that is currently being sampled (veligers) for dreissenids by all agencies in the CRB and determine the appropriate level of sampling to obtain optimal coverage (i.e. probability of detection).

3. **Increase monitoring capacity (sampling and analysis) in the CRB:** Continue investigating the utility of FlowCam system; Consider practicality of establishing a CRB PCR (eDNA)-based laboratory.

F. Interjurisdictional Coordination

1. Ensure that AIS prevention efforts at the local, regional and national levels are coordinated and focused on improving efficiencies, streamline processes and information sharing among the numerous consortiums and entities working in the region.

2. **AIS regional website:** Produce a well-maintained and comprehensive website on regional AIS issues (focusing on, but not limited to dreissenid mussels) to improve information sharing, coordination and collaboration within the CRB.

G. Education and Outreach

1. **Communications plan:** Develop a consistent, multi-year regional AIS prevention communication/outreach/education plan to efficiently coordinate a set of strategic, vector-focused actions by all CRB states (developed and shared with neighboring Canadian provinces).

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II. OVERVIEW

Aquatic invasive species (AIS) are nonindigenous species that pose significant economic, environmental and societal threats to inland, estuarine, and marine waters.

- They threaten the diversity or abundance of native species, ecological processes, and natural resources as well as commercial, agricultural, aquacultural, cultural, and recreational activities.

- They adversely affect the health, well-being and quality of life by disrupting ecological processes and food chains within aquatic ecosystems and access to healthy aquatic environments.

- They threaten the region's fishery resources, including recovery efforts of salmon and steelhead listed under the Endangered Species Act. A dreissenid infestation in any of these salmon-bearing watersheds would be a disastrous step backward for the recovery of these imperiled species, thus there is heightened urgency to implement management initiatives to halt further range expansion. There is particular concern about the impact of dreissenids on submerged fish passage facilities, such as fish ladders, screens and bypass infrastructure.

- Zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena r. bugensis*), also referred to as dreissenid mussels, pose a significant threat to the Federal Columbia River Power System's (FCRPS) hydropower and nuclear generation projects.

Mussel infestations in other infested regions of the country have resulted in raw water users needing to expend significant resources on mitigation. For example:

- Quagga and zebra mussels have cost more in prevention and control than any other aquatic species to invade the United States, costing an estimated $5 billion in prevention and control efforts since their arrival in the 1980s.

- The quagga mussel infestation of water supply pipes, dams, and other infrastructure has cost the Metropolitan Water District of Southern California about $35 million over the last six years, with costs expected to continue into the future.

- The Bureau of Reclamation at Hoover Dam spends $1 million annually on quagga mussel control.

These mussels "hitchhike" to new water bodies by attaching to trailered watercraft and other equipment in contact with the water. They can survive out of the water for about two weeks. Because of their ability to move overland between water bodies, both zebra and quagga mussels are now found in close geographic proximity to the Columbia River Basin (CRB) (**Figure 1**).

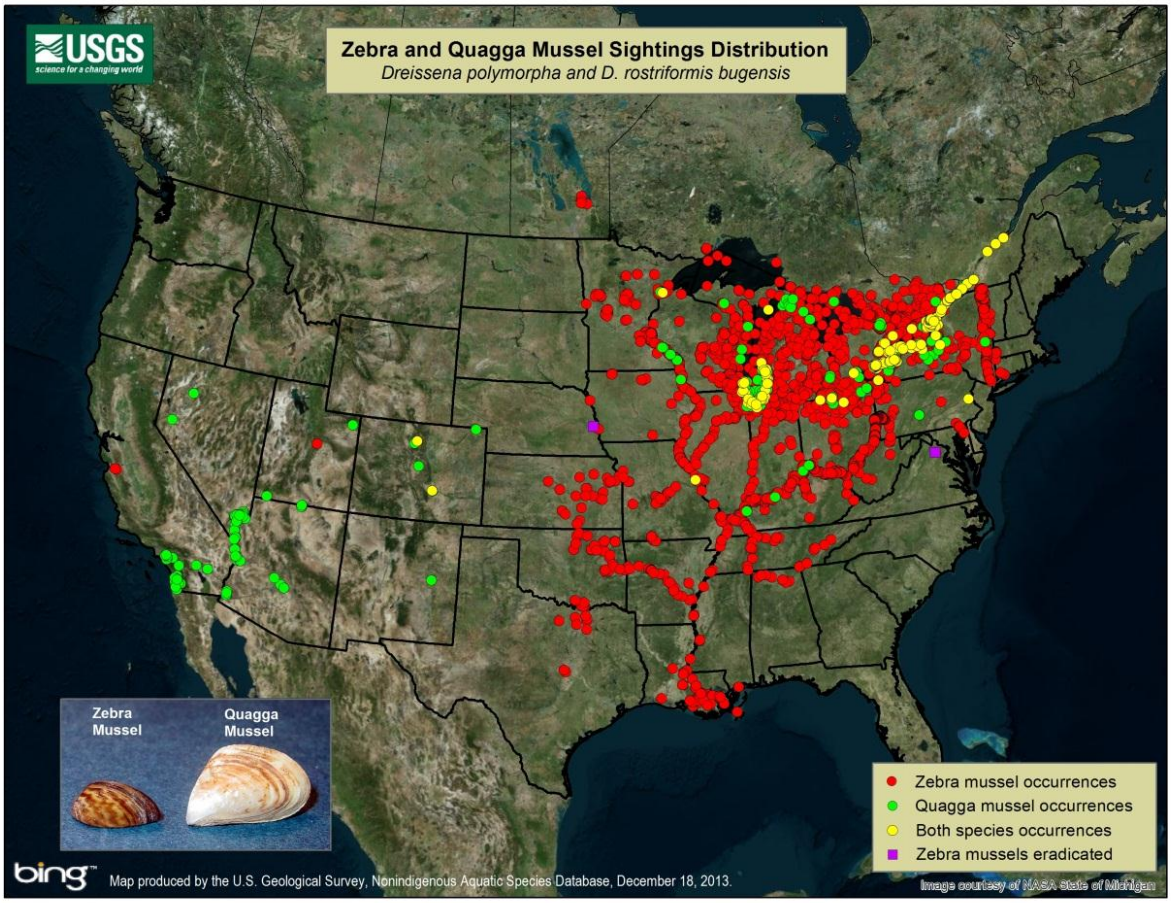

Figure 1. Zebra and quagga mussel sighting distribution (*Source:* USGS, Zebra Mussel and Quagga Mussel Information Resource Page, Gainesville, Florida).

In response to the threat posed by dreissenid mussels and other AIS,[1] the Pacific States Marine Fisheries Commission (PSMFC), state and federal government natural resource agencies and tribal sovereign nations employ a multi-faceted programmatic approach to prevent and/or minimize the impacts of AIS. Current programmatic elements include prevention, management, monitoring, research, coordination, and outreach. The primary interjurisdictional coordinating group for AIS program activities is the CRB Team of the 100th Meridian Initiative, a group supported with financial resources from both the Bonneville Power Administration (BPA) and US Fish and Wildlife Service (USFWS).

The majority of agency resources spent on preventing the introduction of mussels into the CRB are spent on watercraft inspection and decontamination (*see Section A.1 "Watercraft Inspection"*). To stop the spread of mussels by trailered watercraft, western states operate

[1]Although dreissenid mussels are the highest priority threat to the region and garner the most attention and agency resources, other AIS of concern include flowering rush, New Zealand mudsnail, hydrilla, estuarine cordgrasses, European green crab, Chinese mitten, marine tunicates, and various freshwater fish species. However, this document focuses on dreissenid mussels as they pose the highest risk to the FCRPS.

watercraft inspection stations. In 2012, state and local agencies inspected more than 900,000 watercraft; they intercepted more than 350 contaminated watercraft, and more than 100 of these vessels were contaminated by invasive mussels. Nearly 75 percent of the mussel-contaminated watercraft were sourced from the lower Colorado River region (i.e., Lakes Mead, Havasu, and Mohave).

Numerous federal and state government, tribal sovereign nation, and academic institutions are actively monitoring for dreissenid mussels (and other AIS) within the CRB (*See Section E "Monitoring")*. Most detection efforts are focused on planktonic larvae. Larvae are collected with a plankton net, and then a laboratory inspects plankton samples for the presence of these mussel larvae using cross-polarized microscopy. One of the laboratories in the region, located at Portland State University (PSU) Center for Lakes and Reservoirs, is funded by the BPA and PSMFC. Additionally, the Technology Innovation Program currently is funding a Washington State University / US Geological Survey (USGS) project relative to the use of FlowCam (a particle analysis instrument using digital imaging to measure particle size and shape). Monitoring for adult mussels also occurs, but the majority of the time and effort is spent on larval mussel detection because of the assumption that larval mussels have a higher probability for early detection.

Data sharing and mapping from the numerous monitoring programs in the region are coordinated through USGS and PSMFC. Information is shared and posted online on the CRB AIS Database website (Dreissenid mussel monitoring data can be found at: http://crbais.psmfc.org/monitoring/monitoring-for-aquatic-animals/zebraquagga-mussel-2012).

Despite dedicated efforts by state natural resource management agencies to prevent the spread of mussels into the CRB, the region requires coordinated efforts to prepare for their arrival. For example, hydropower projects must undertake system vulnerability assessments to identify management strategies and cost options for long-term mitigation of a mussel infestation (*See Section C.1 "Vulnerability Assessments*"), including identifying which actions or technologies are best suited for maintaining water operations and reducing operations and maintenance costs. Facility planning must also include needed regulatory permits for the use of biocides for both mitigation (*See Section C.2 "Mitigation")* and eradication (*see Section B.1 "Dreissenid Mussel Eradication"*).

An important component of the vulnerability of the FCRPS to dreissenids will be the densities that can be supported by CRB waters. Although it is generally accepted that mussels could survive throughout the basin, managers need as much information as possible on the degree of risk posed by dreissenid mussels once they arrive. It is likely that significant impacts to the FCRPS from a reproducing population of dreissenid mussels would likely not take place in the first two years after introduction. Research into potential impacts of dreissenid mussels needs further research (*See Section D "Research")* to best understand the long-term economic, environmental, and societal threats to these waters and the associated human activities.

Education on invasive species identification, impacts and management is critical to effective prevention efforts. The most common products used by CRB agencies are brochures (*Zap the Zebra!*), videos (*Don't Move a Mussel*) boat ramp signs and highway billboards, and other

graphics and campaigns aimed at specific audiences or advancing specific messages (*See Section G "Education and Outreach")*.

In addition to the overview and recommendations in this document, there are other regional AIS prioritization and planning efforts and action plans that have been developed by regional planning groups.[2] They include:

1. **Preventing an Invasion:** The Pacific NorthWest Economic Region, the Northwest Power and Conservation Council, PSU Center for Lakes and Reservoirs, and PSMFC sponsored a workshop on May 15, 2013 entitled, "*Preventing an Invasion: Building a Regional Defense against Quagga and Zebra Mussels*." Workshop outcomes included a set of action items addressing the challenges and barriers to prevent the introduction of invasive mussels to the Pacific Northwest. The information on this website includes the presentations from the workshop and the action plan that was developed to address prevention efforts in the Pacific Northwest.

2. **Legal and Regulatory Efforts to Minimize Expansion of Invasive Mussels through Watercraft Movements:** On August 22–23, 2012, a workshop was hosted by the Arizona Game and Fish Department and convened in Phoenix, Arizona, by the US Fish and Wildlife Service (USFWS), the National Association of Attorneys General, Oregon Sea Grant, the National Sea Grant Law Center, and the Western Regional Panel (WRP) on AIS. The purpose of the workshop was to engage Assistant Attorneys General, natural resource agency attorneys, law enforcement supervisors, policy makers, and the AIS Coordinators from the 19 Western states, interstate organizations, and federal partners to establish legal and regulatory approaches and opportunities for AIS abatement and reform. One deliverable from this workshop was the creation of an action plan that articulates needed actions at the federal/national, regional, state and local levels to minimize the expansion of invasive mussels through watercraft movements in the western United States.

3. **Building Consensus in the West:** To advance three specific action items from the Phoenix meeting action plan (developing standard definitions and criteria and model statutory/regulatory language to implement a comprehensive watercraft inspection and decontamination program), representatives from western states convened August 13–15, 2013, in Denver Colorado for a workshop titled, "*Building Consensus in the West—A Multi-State Vision for Watercraft Inspection Programs*."

4. **Pacific NorthWest Economic Region (PNWER):** The PNWER Invasive Species Working Group has developed a set of AIS action items.

5. **Quagga-Zebra Action Plan (QZAP) for Western Waters:** This 2010 document developed by the WRP on AIS identifies and prioritizes specific actions that are needed to prevent the further spread of these mussels in a comprehensive way.

[2] Many of the action items from these documents are reflected in this document.

III. AIS PREVENTION EFFORT THEMATIC AREAS

A. Prevention

A.1 Watercraft Inspection

The most likely vector for mussels to be introduced into the CRB is by infested watercraft and waterborne equipment. The CRB is a boater destination and therefore receives watercraft traffic from throughout the United States and parts of Canada (See **Figure 2**). To address this threat, during the past five years, most of the 19 western states have passed legislation, promulgated regulations, and implemented boat inspection programs and public outreach campaigns to prevent the spread of quagga and zebra mussels in the western United States through the movement of watercraft (Showalter-Otts and Bowling 2013). In the Pacific Northwest, permanent roadside watercraft inspection programs have been established in Idaho, Montana, and Oregon[3]. The locations and operating hours of inspections stations in the CRB for 2013 are shown in **Figure 3.**

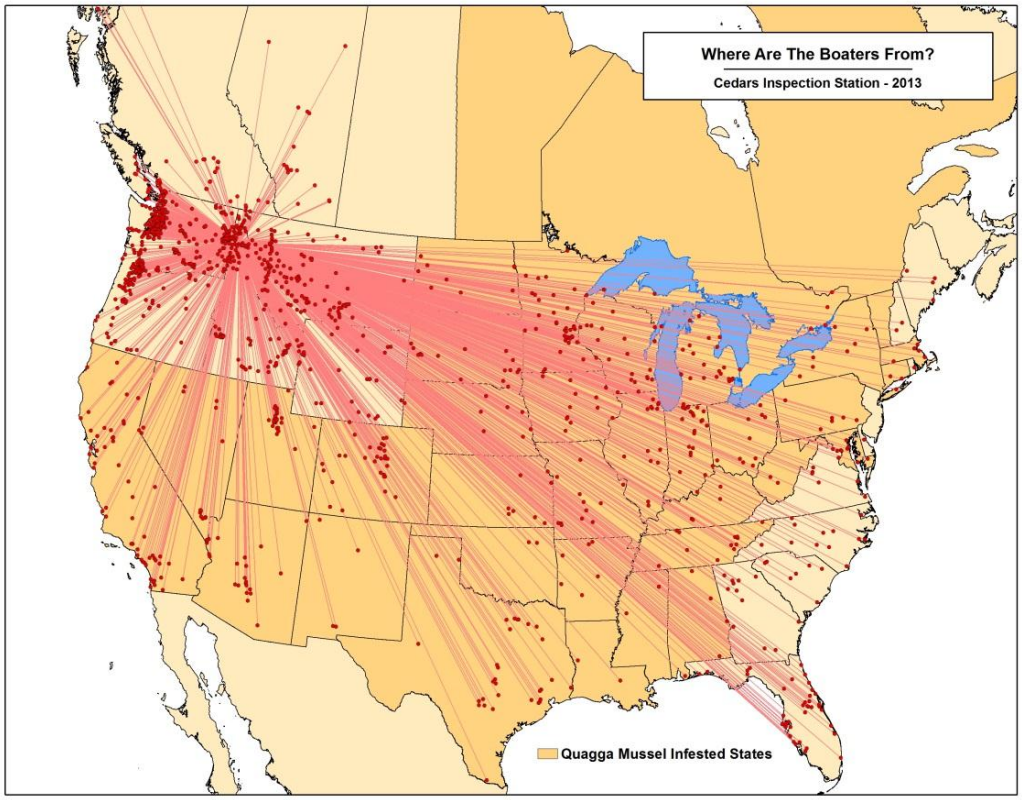

Figure 2. 2013 Sources of watercraft intercepted by the Idaho Department of Agriculture's "Cedars" Inspections Station (Interstate 90) (Source: Stephen Cox, ISDA).

[3] Washington uses temporary roving watercraft inspection stations. Wyoming established a roadside inspection station program in 2013.

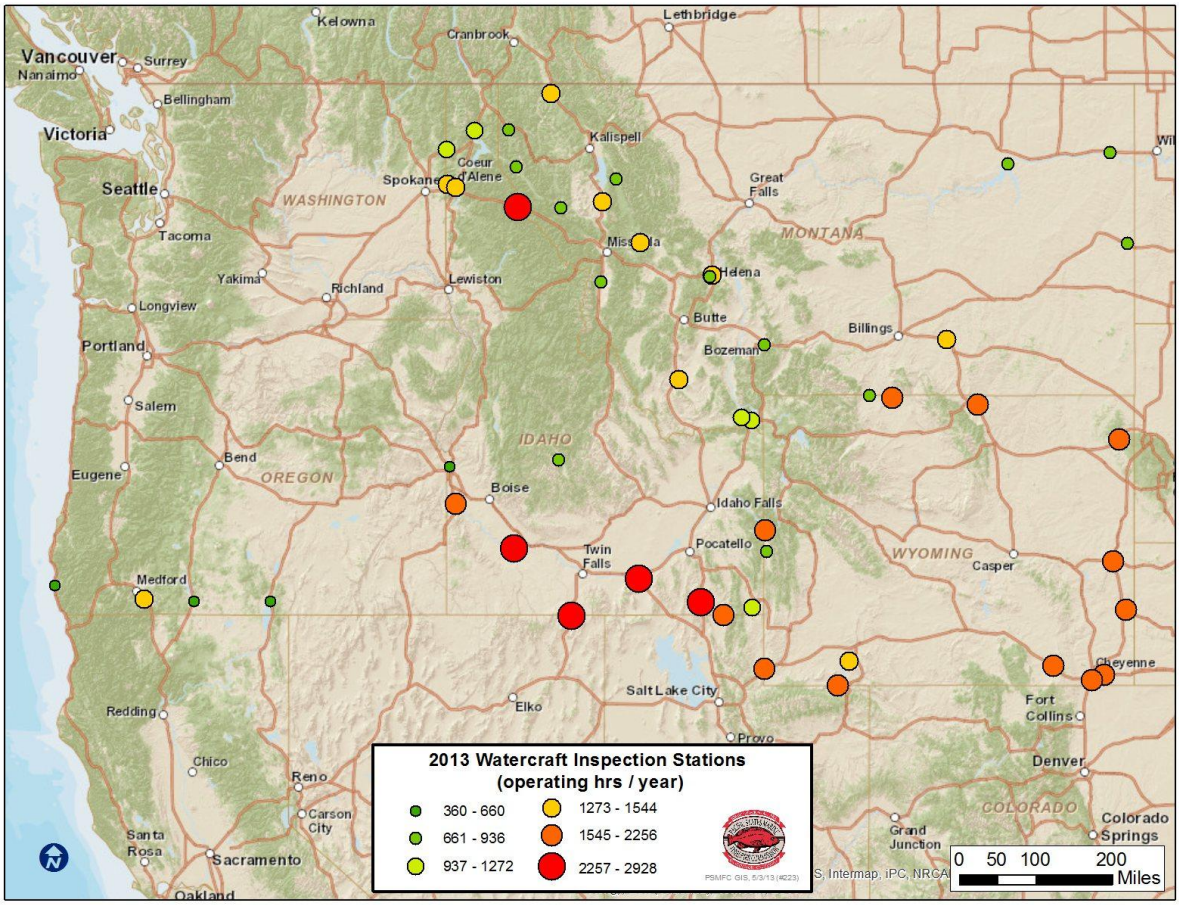

Figure 3. Locations and operating hours of inspections stations in the CRB (2013).

The majority of agency resources for preventing the invasion of mussels into the CRB are spent on watercraft inspections. In 2012:

- About $2 million was spent on watercraft inspection programs in Oregon, Washington, Montana and Idaho.

- The four CRB states inspected over 100,000 watercraft with over 100 mussel contaminated watercraft intercepted. Nearly 75 percent of the intercepted boats were from the lower Colorado River region (i.e., Lakes Mead, Havasu, and Mohave).

To effectively stop the spread of dreissenid mussels requires a perimeter of watercraft inspection stations around the CRB as well as improved efforts to decontaminate fouled watercraft at their source. State agencies, tribal sovereign nations and numerous groups, including the NWPCC, PNWER and PSMFC, have been requesting that the Department of Interior (and National Park Service) increase efforts to decontaminate watercraft at Lake Mead National Recreation Area.

Because of budget constraints, however, watercraft inspection and decontamination (WID) stations are only open seasonally and usually closed during nighttime hours.[4] As a result, state aquatic invasive species managers are concerned that contaminated boats are passing through these defenses. Additional watercraft inspection time and geographic coverage to form a perimeter defense is needed to help prevent an introduction. More WID station time might be applied on Sundays, at night, during off -seasons, and at more locations (IEAB 2013).

The number of existing watercraft inspection locations and the wide range of agency/organization capacity (funding, authority, access, control and political will) to implement them make program consistency across jurisdictional boundaries a critical need. Additionally, as evidenced by Figure 2, watercraft owners often travel through several jurisdictions and interact with more than one watercraft inspection station. Agencies have also witnessed frustration from the boating public, especially low-risk boaters, about being re-inspected in more than one jurisdiction. Therefore, interjurisdictional coordination and cooperation is a critical element of western WID programs.

To implement WID interjurisdictional program consistency and enhance communication, several efforts have been accomplished or are underway in the western states:

- **Uniform watercraft decontamination/inspection protocols and standards**: All WID programs seek confidence that neighboring jurisdictions are properly inspecting and decontaminating watercraft (Giusti 2010). The document "Uniform Minimum Protocols and Standards for Watercraft Interception Programs for Dreissenid Mussels in the Western United States" (Zook and Phillips 2012) provides the technical information for decontamination and inspection.[5] Western AIS managers are in the process of updating this document.

- **Quality Control and Training Standards:** WID program staff and technical field staff need to be trained according to recognized protocols and standards (see above). The majority of state WID staff AIS program personnel are trained at the PSMFC-sponsored Level Two WIT Training program (and after taking the WIT II class, graduates train staff in their respective jurisdictions). Field staff also need to be periodically tested on their inspection capability. Western AIS programs are currently working on a regionally accepted field testing program for inspection station staff.

- **Electronic Data Collection System:** There are currently different systems in use throughout the western United States for the purpose of collecting data at WID stations. Most WID programs initially collect information and assess the risk of watercraft, however, manual data entry from paper to digital form is slow, expensive and error-prone. Wyoming, Montana, Utah, Colorado, Idaho, and Lake Tahoe now use electronic data collection methods. The priority data records to share are those from high risk

[4] For example, there are 8,760 hours in a year and most inspections stations, being open seasonally, are only open for a maximum of about one-third of the year (See Figure 5).
[5] Colorado's Watercraft Inspection and Decontamination and Procedures (Brown and Seagle 2013) is also used as a regional reference and has similar technical recommendation the Zook and Phillips (2012)

watercraft leaving AIS-positive or infested waters within the last 60 days.[6]

- **Reciprocity Agreements:** States have begun the process, through agreements, to develop reciprocity for inspections for low risk watercraft (i.e., watercraft that are from uninfested waters). This has not formally been completed in the CRB, though there is a level of trust and communication among the CRB states. Development of reciprocity agreements is critical to the development of a regionally coordinated and efficient inspection program. Reciprocity is also necessary for expansion of the Idaho boaters' "passport" system to facilitate handling of low-risk trailer vessels.

- **Authorities:** State legal and regulatory authorities related to the movement of AIS by trailered watercraft need to ensure consistency across borders. Currently a legal team working with attendees from the Phoenix/Denver Workshops are developing "model" state AIS legislation.

RECOMMENDATIONS FOR FUTURE WORK:

1. Interception of mussel-contaminated boats when they enter the mussel-free region of the Pacific Northwest is most effectively and efficiently conducted at the perimeter of the region. At present, states in the Pacific Northwest conduct boat inspections within (or at) their borders. These inspection stations have proven effective, intercepting hundreds of contaminated watercraft in the past several years, but there are gaps in coverage that need closing. Additionally, development of processes and policies that permit states to function as a unit by pooling resources to jointly fund and prioritize locating regional border inspection stations could allow these stations to remain open longer, intercept more boats and more effectively protect the region from mussel introduction.

2. Continue development of a western regional shared watercraft inspection and decontamination electronic database that will assure real-time communication about movements and inspection of high risk boats in West.

3. Continue to pursue the implementation of a regional AIS Passport system.

4. Continue to work with federal partners (i.e., Department of Interior) to increase decontamination efficiencies at federally managed water bodies (e.g., Lake Mead).

5. Continue to implement cooperative/reciprocal agreements between jurisdictions conducting watercraft inspections and decontaminations.

[6] Suspect/reported infested watercraft en route to/through western states (i.e., from the Great Lakes/Lake Mead) are reported through the WEST911 email alert system.

A.2 Watercraft Decontamination

Decontamination of watercraft by resource agencies is accomplished through hotwater pressurized wash. Decontamination programs vary in scope, but all require decontamination of all areas that come into contact with raw water, including the exterior of the watercraft, interior compartments, all raw water plumbing and ballast tanks.

The objective of decontamination is to kill and remove, to the extent practical, all visible mussels. A properly conducted hot pressure wash has been scientifically field tested and currently is the only technology that has proven effective in killing mussels (Zook and Phillips 2012). However, removing all mussels , especially from heavily fouled large watercraft has proven challenging. Removing dead mussels is also important because a false positive finding may result from the presence of mussel shells or DNA in samples collected for genetic analysis (polymerase chain reaction {PCR}). This can result in unnecessary concern and expensive action if unexplained shells drop or are scrapped-off the hull and are subsequently discovered at a boat ramp or the lake bottom, or if the watercraft is intercepted in transit.

Therefore alternative methods to hot spray watercraft decontamination have been proposed pursued over the years. Alternative systems include drying time acceleration, "dip" tanks, dry ice blasting, semi-automated wash systems, and chemical treatments[7] . Each of these systems has unique features that may be suitable for wider use in the future. However, an alternative decontamination technology has not been rigorously field tested to date, and therefore hot pressure wash is still the most widely used decontamination technology.

One new technological advancement that has moved forward in the past year is ballast water filtration. Watercraft decontamination experts have found that ballast water tanks are the most problematic area to decontaminate as the vast majority of water ballast systems are impossible to visually inspect, and most do not fully drain water (Zook and Phillips 2012). The remaining water has been shown to harbor the larval stage of dreissenids (veligers) and may contain other aquatic invasive species as well. Recent research has found that veligers can survive in ballast tanks up to 27 days, which has further raised concerns amongst resource managers regarding this vector (Choi et al. 2013; Dalton and Cottrell 2013). Without a method to visually inspect or otherwise ensure that a given ballast tank does not contain invasive species, many western programs require that most (or all) ballast tanks be flushed with 120-140°F water to kill any organisms that may be alive in the ballast water or attached to the sides of the tanks. Depending on the number of ballast tanks onboard, this process can involve the use of over a hundred of gallons of water, is labor intensive, uses up valuable public resources, and inconveniences boaters. The need to decontaminate ballast tanks has also resulted in higher boater fees at some water bodies. In addition, some invasive species prevention programs may temporarily deny boaters access to waters if ballast tanks are not fully drained or decontaminated.

[7] For example Several manufactures such as Sublime ® and RYDLYME are water descalers that dissolves mussel shells

STATUS:

To address the ballast tank vector, the University of Nevada Reno is in the final stages of completing its testing of a ballast water filtration system developed by the watercraft industry for recreational watercraft. Initial results from the testing, conducted at Lake Mead, Nevada, have showed good results in removing veligers. This project includes extensive collaboration between state and federal agencies and the watercraft industry to insure that the system is not only effective at reducing the risk of spreading invasive species, but also appears to be cost effective to the manufactures and boaters.

Other efforts are also underway on reducing the risk of the watercraft vector. For example on the national level, the Aquatic Nuisance Species Task Force Meeting has brought together the watercraft industry, marina operators and state and federal AIS agency personnel to seek approaches to developing "Semi-Green" watercraft[8].

RECOMMENDATIONS FOR FUTURE WORK:

1. Seek to develop additional technologies for watercraft decontamination that are effective in killing and removing dreissenid mussels.

2. Work with watercraft/recreational industry partners in the development of watercraft designs that reduce the threat of spreading AIS.

B. Management

B.1 Dreissenid Mussel Eradication

If mussels are found in the mainstem of the Columbia River, it is unlikely eradication will be possible, however, if they are found at a boat ramp or embayment on the Columbia River, where a section of the water can be isolated and treated, eradication may be feasible. It is critical that state and federal water resource managers develop their own planning mechanisms because each jurisdiction differs in its regulatory requirements for mussel eradication. This is especially important for environmental compliance issues, as the eradication of a mussel population will almost certainly employ a biocide. The use of biocides or other mitigation techniques may require permits under the Clean Water Act (CWA), ESA, FIFRA, and NEPA (state and federal). Some of these permits may also be applicable for the owners and operators of hydropower facilities and other raw water user facilities in the Columbia River Basin that consider using biocides and other mitigation techniques.

In 2013, a Rapid Response Working Group (RRWG) was formed. The group consists of 20 active individuals with knowledge of and/or responsibilities for responding to an introduction of dreissenids in the CRB. On December 11, 2013, RRWG held an exercise to ensure all the tools, permissions, and procedures exist to undertake eradication in Oregon and Washington. [Note:

[8] Watercraft that are designed to reduce threat of spreading invasive species and include potential technologies such as filtration systems, antifouling hull paints, etc.

Because of the similarities in how Oregon and Washington process permits associated with control options for invasive mussels, the workshop was focused on scenarios for both Oregon and Washington.] The objectives of the workshop were to:

- Discuss existing state and federal permitting processes associated with a potential management action in response to the introduction of invasive Dreissenids in Oregon or Washington.

- Conduct scenario exercises for both states to reinforce actions that will need to be taken to implement a management response.

- Create a list of action items and associated timelines to address any unresolved issues and to further advance the ability of Oregon and Washington to respond to an introduction of invasive Dreissenids.

Workshop attendees included key federal and state agency representatives associated with invasive dreissenid control and permitting issues, as well as several other individuals representing other states and organizations from the RRWG.

An emphasis was placed on the development of key action items to advance the ability of the states of Oregon and Washington to respond to an introduction to invasive mussels.

The report from December 11 exercise, including information learned and all action items, can be found in @ http://preventinganinvasion.psmfc.org/wp-content/uploads/2013/08/Summary-Report-Rapid-Response-Working-Group-meeting-on-December-11-2013.pdf

RECOMMENDATIONS FOR FUTURE WORK (below is an abbreviated list of actions items, the full list can be found in the link to December 11 exercise report)

1. Pesticide Registration—Refine the list of registered Section 3 pesticides for Oregon and Washington, designating which would most likely be used to control an introduction of invasive mussels.

2. Take steps to ensure the most likely products to be used for invasive mussel control are listed as Section 3 pesticides in each state.

3. Section 18 of FIFRA—Explore opportunities to respond to an introduction of invasive mussels by developing the components of a Section 18 (which would authorize an unregistered use of a pesticide for a limited time if EPA determines emergency conditions exist) that can be applied for regionally.

4. Begin taking steps to conduct a programmatic consultation for the region by working with the National Oceanic and Atmospheric Administration/National Marine Fisheries Service (NOAA/NMFS) and the USFWS to assimilate existing information and identify key information gaps needed to inform its development.

B.2 Rapid Response Preparedness

The purpose of the *Columbia River Basin Interagency Invasive Species Response Plan: Zebra Mussels and Other Dreissenid Species* (CRB Plan) (CRB Team, 2011) is to coordinate a rapid, effective, and efficient interagency response to delineate, contain, and when feasible, eradicate zebra, quagga, and other dreissenid mussel populations if they are introduced in CRB waters. Recognizing that dreissenid mussels typically establish firmly in a watershed prior to detection, the CRB Plan assumes that a detected population has not dispersed widely or reproduced (i.e., eradication is still reasonable to consider) until further analysis reveals otherwise. The provisions of the CRB Plan are intended to enhance interagency coordination beginning with the discovery of an infestation through containment and initial control efforts. Long-term monitoring and control of a permanent infestation will require a separate management plan developed and implemented by the individuals or organizations with authority and responsibility for managing the infested site(s).

In addition to the CRB Plan, it is critical that states develop their own planning mechanisms because each state differs in its history of dealing with aquatic invaders, its agencies and authorities, and its capacity for a coordinated management response.

At the water project level, development of vulnerability assessments (*See Section A.2 "Vulnerability Assessments and Facility Planning"*) of facilities that use raw water are important because facility managers need to be prepared to address the consequences of an infestation.

STATUS:

Progress on state dreissenid rapid response plans has included the release of the State of Idaho's Dreissenid Mussel Prevention and Contingency Plan (IDA 2012) and Oregon's Dreissenid Mussel Rapid Response Plan (Draheim et al. 2013). The State of Washington is currently in the process of developing a rapid response plan, and a plan is expected to be completed by Summer 2014. Montana is still considering whether they will undertake rapid response planning in 2014.

RECOMMENDATIONS FOR FUTURE WORK:

1. The states of Washington and Montana need to complete their dreissenid rapid response plans.

2. The State of Idaho needs to update its Contingency Plan based on information developed from the December 11 Oregon-Washington Rapid Response Working Group meeting.

C. Vulnerability Assessments and Mitigation

C.1 Vulnerability Assessments

Dreissenid mussels are aggressive bio-foulers. When present in raw cooling water, they can seriously jeopardize industrial facilities using this water unless defensive steps are taken. A vulnerability (AKA "facility") assessment is a detailed analysis of existing structures to determine potential impacts of a dreissenid mussel infestation. A facility assessment process usually requires considerable time for planning and coordination, background research, site visits, evaluation of data and preparation of a report. The specific risks and problems that a particular facility will have with a dreissenid introduction will depend on:

- how the raw water enters the facility;
- any processes to treat or transform the water for various facility applications;
- the routing of all piping branches and location of components and equipment, including materials of construction; and
- the operating envelope of the various water systems (e.g., maximum and minimum flow rates, frequency of operation, temperature ranges).

STATUS:

In July 2013, PSMFC (with support from BPA) formed a Vulnerability Assessment (VA) Team comprised of state, federal, provincial (British Columbia) and private hydropower interests, including BPA, USACE and BOR representatives. The first task of the VA Team was to undertake a survey to determine the status of VA's in the CRB. Survey results indicate that of the 75 most prominent hydropower facilities in the CRB, VA's have been completed for the John Day and Dalles projects (Claudi and Prescott 2010) and Bonneville project (Athearn and Darland 2007) and 14 VA's are planned and budgeted in the next two years.

The VA Team developed a draft document prioritizing high-risk facilities (based on likelihood of infestation (e.g., calcium content), presence of fish passage facilities and whether a VA has been competed or planned (See **Figure 4**). For example, Willamette River Basin Hydro projects (e.g., Detroit, Cougar) are likely at lower risk to the detrimental effects of invasive mussels because of lower water calcium levels. In comparison, the upper Snake River Projects (e.g., Minidoka, American Falls) are likely at higher risk. After assembling this information, the group is taking next steps to create a "road map" for completing additional VA's, including seeking how hydropower project operators can create efficiencies by working together to conduct "batch" assessments (3–4 assessments during a narrow window of time, e.g., one to two weeks), leveraging similarities among like facilities and/or facilities within close proximity to one another. The report from the VA Team currently entitled "*Funding Strategy to Conduct*

Vulnerability Assessments for High Priority Columbia River Basin Hydropower Facilities" is expected to be released in the Spring of 2014. Information developed by the Rapid Response Working Group (*see Section B.1*) will be used to develop potential mitigation strategies, including the permitting of biocides.

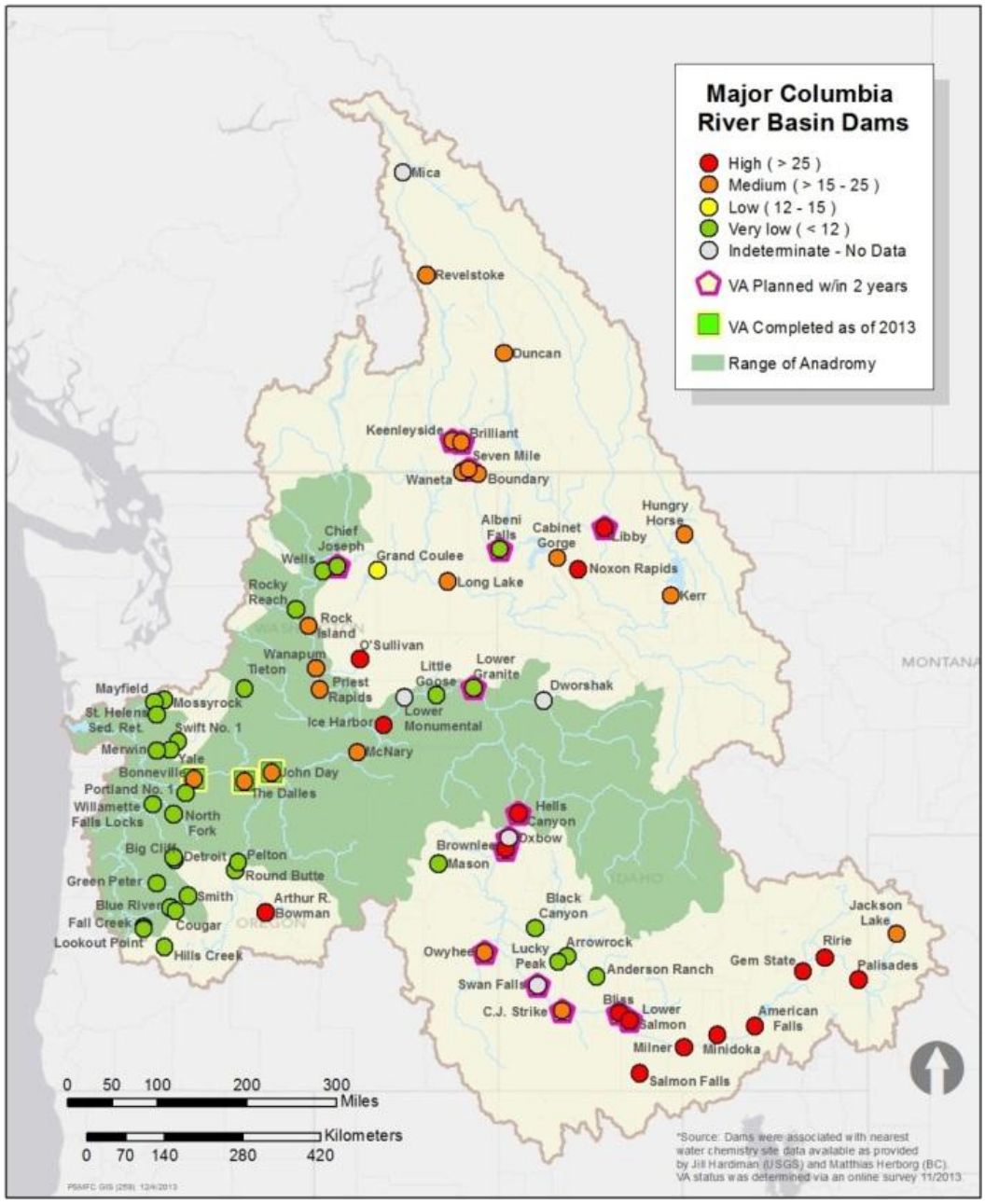

Figure 4. Risk of establishment of dreissenid mussels (based on dissolved calcium) for 75 of the most prominent hydropower facilities in the CRB, and vulnerability assessments competed and planned. (*Map Source:* Van Hare, Pacific States Marine Fisheries Commission.)

RECOMMENDATIONS FOR FUTURE WORK:

1**.** Complete Vulnerability Assessments at Hydropower Projects In The Columbia River Basin.

- Continue to work with the management authorities responsible for the hydropower facilities that did not respond to the survey request to obtain their status on vulnerability assessments for their facilities, particularly the Bureau of Reclamation, which has a significant number of facilities within the basin.

- Work with PUD's to determine if additional resources are needed to develop comprehensive vulnerability assessments for the facilities in which they reported system walkthroughs.

- Encourage all management authorities that have not yet completed vulnerability assessments to provide updates to the online tool as they make progress in planning, budgeting for, and completing vulnerability assessments.

- Identify any additional facilities (beyond the original 75 structures targeted for this initial initiative) that should be included in future analyses, either because of their presence within the extent of anadromous waters, or other key factors.

- It is estimated the cost to conduct remaining vulnerability assessments for high and medium risk prominent hydropower facilities in the CRB is $470,000. Next steps include further examination of bundling opportunities based on characteristics of hydropower facilities and proximity to one another.

C.2 Mitigation

Vulnerability Assessments should also include management strategies and cost options for long-term mitigation for a mussel infestation (i.e., identifying actions or technologies best suited for maintaining water operations and reducing operations and maintenance costs or other expenses). Various conventional technologies have been used with reasonable success.

The RRWG updated dreissenid Control Options (Appendix D) of the CRB Interagency Invasive Species Response Plan: Zebra Mussels and Other Dreissenid Species (CRB Team 2011). The document provides conventional as well as experimental options, each of which has advantages and disadvantages. There are a number of commercial treatment products that have not been listed, but may be applicable in various situations. Current technologies that have been used in raw water (e.g., turbine cooling lines) in the Lower Colorado and Great Lakes regions include Sodium Hypochlorite, ultraviolet light, Zequanox® (biopesticide) and micro-filtration.

At the December 11, 2013 meeting, state and federal agency members of the RRWG in Oregon and Washington (and additional appropriate agency representatives from outside the working group but with permitting authorities) navigated through the permitting processes associated with a management response (e.g., application of copper sulfate) should there be an introduction of

these mussels to an Oregon or Washington water body (*See Section B.1 "Dreissenid Mussel Eradication").* It has been the experience of project agencies that obtaining permits for mitigation use in closed water systems (e.g., fire suppression, turbine cooling lines) is much easier than open water applications. The CRB poses some unique challenges for the use of biocides in mitigation because of Endangered Species Act considerations (e.g., salmon and steelhead) and the necessary environmental assessments that would need to be undertaken before a product is approved.

STATUS:

Two studies have been conducted in the past eight years that provide information on potential mitigation technologies for the FCRPS (Sodium Hypochlorite and anti-fouling paint):

1. Potential Economic Impacts of Zebra Mussels on the Hydropower Facilities in the Columbia River Basin (Phillips et al. 2005)

   The purpose of this study was to estimate costs to FCRPS hydroelectric projects in the event of a zebra mussel infestation. The estimated cost for a hypothetical zebra mussel mitigation strategy, based upon two response scenarios (a sodium hypochlorite (NaOCl) injection system and anti-fouling paint), at 13 select hydroelectric projects, was $23,621,000. The cost per generator was $62,599 for the NaOCl system, and $81,000 for antifouling paint (not including labor). [Note: For a better estimate of antifouling paint costs and utility see study by Wells and Sytsma (2013) below.]

2. Estimating costs of using foul-release type coatings to mitigate *Dreissena* sp. mussel macrofouling at a FCRPS facility (Wells and Sytsma 2013).

   Portland State University investigators are conducting this ongoing Bonneville Technology Innovation Program project (number 233) to evaluate the effective service life foul-release coatings in the Columbia River to mitigate the impacts of invasive zebra/quagga mussels. Panels with foul-release coatings were deployed beginning in 2012 and are being removed at periodic intervals (through 2014) to assess durability and ability to resist fouling by quagga mussels. This information is necessary to determine the cost-effectiveness of coatings for maintaining the functionality of multiple structures at hydropower facilities, including fish screens and fish ladders.

   As part of this project, the document "*Estimating costs of using foul-release type coatings to mitigate Dreissena sp. mussel macrofouling at a FCRPS facility*" was released in November 2013 (available upon request). The study estimated it would cost $1,111,855 to apply the Sher-Release/ Duplex foul-release coating system (manufactured by FUJIFILM Smart Surfaces LLC) to 1,300 diffuser gratings and 156 flat steel bars that are part of the auxiliary water system (AWS) in the adult fish passage facilities at The Dalles Dam Project. The total surface area of the AWS diffuser gratings and bars is 10,390-m2 (111,832-ft2), thus the total estimated cost for application, including labor, equipment/supplies and other direct costs is $107/ m^2 ($9.94/ ft^2). The work to remove

the gratings and bars, apply and cure paint, and reinstall would need to be completed during the in-water work period, which is December to mid-January for the East ladder and mid-January through February for the North ladder. [Note: This document has been provided to BPA.]

RECOMMENDATIONS FOR FUTURE WORK:

1. **Mitigation Strategy Options:** Further development of updated mitigation strategy options (both physical and chemical) that including cost estimates for hydropower facilities and fish.

    - Develop inventory of highest priority mitigation technologies suitable for FCRPS hydropower and fish facilities.

    - Solicit a Request for Proposals to create mitigation management plans for FCRPS hydropower and fish facilities (including cost estimates).

    - Coordinate efforts within the CRB to continue research into foul-release coatings, and sharing the results of the research with regional entities.

2. **Environmental Permitting:** Initiate environmental permitting process (i.e., National Environmental Policy Act (NEPA), Endangered Species Act (ESA), Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)) with appropriate regulators for use of cost effective mitigation technologies identified above at FCRPS hydropower and fish facilities.

    - Build on the work currently undertaken by the RRWG.

D. Biology

An effective *Dreissena* sp. treatment and control program in the CRB includes proven technologies, operational flexibility, rapid implementation, and cost effective and dependable strategies. It is difficult to estimate the population density and growth rates of reproducing dreissenids in the CRB, yet mussel density and growth rate dictate the cost of mitigation. There are examples of hydropower management agencies purchasing mitigation equipment that was never used. For example, in 1993, an automated chlorine injection system was installed at two of the nine USACE Nashville District hydropower plants in the Cumberland River Basin to protect its raw water systems from zebra mussel infestations. These systems were never used because zebra mussel populations did not reach significant nuisance levels to warrant their use (Phillips et al. 2005).

Dreissenid mussels need calcium to build their shells. The larval forms of dreissenids (veligers) require higher levels of calcium to develop than is required by adult mussels for survival. Therefore, if adult mussels are introduced into a body of water with low calcium, the adults may

survive for some time, but the population may fail to reproduce and will likely not become an established and reproducing population. Calcium is considered the most essential environmental constituent when assessing the likelihood of long-term mussel survival in the CRB. The data available from the CRB generally shows calcium levels that would be considered adequate to support low population levels of dreissenid mussels (based on data for zebra mussels from eastern North America and Europe) (Claudi and Prescott 2010). There are areas of the CRB (e.g., Southeastern Idaho) where calcium levels are high enough (over 20 mg/l) to support a potentially robust population (See **Figure 5**).

Preliminary results from the Bonneville Technology Innovation Program study, "Quagga Mussel Growth and Survival" (project number 232) suggests that lower calcium water calcium waters may support quagga mussels as follows:

- On average, quagga mussels were able to survive and grow in water from the Columbia mainstem.

- 19% of the mussels reared in untreated water from the Willamette River gained weight.

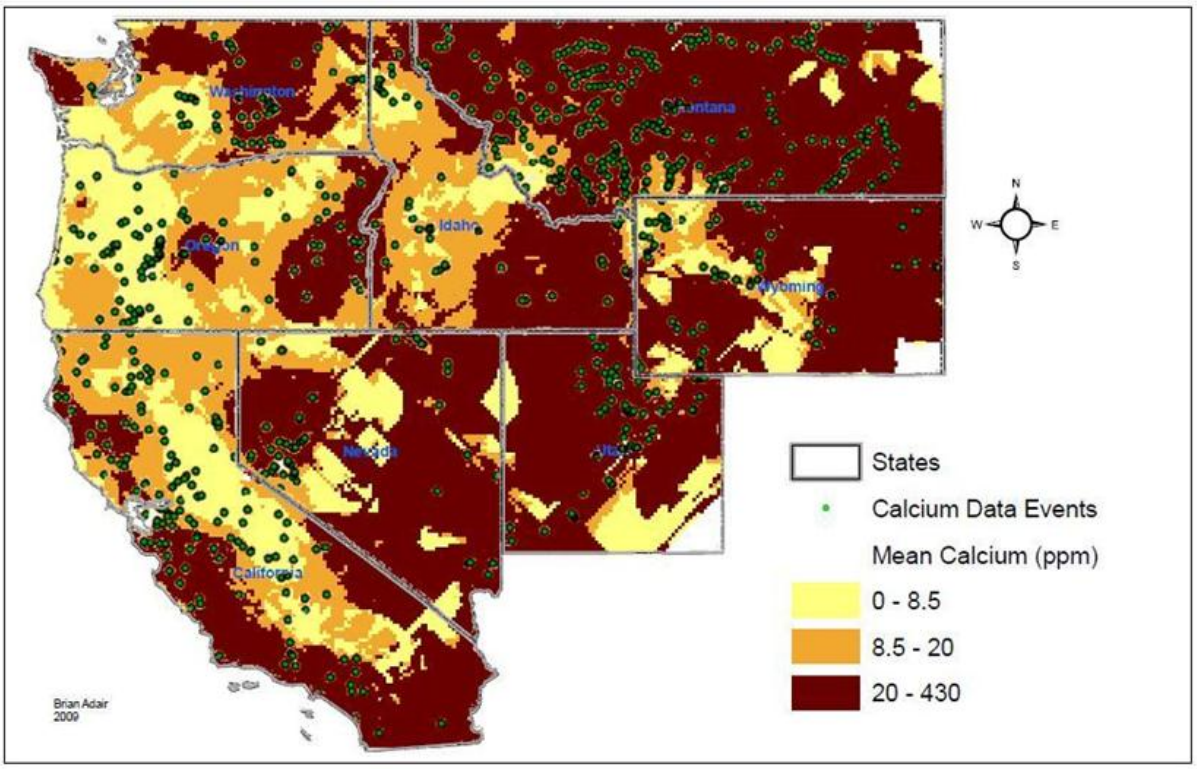

Figure 5. Universal Kriging map of the CRB and Greater Northwest showing predicted calcium concentrations as regional contours. The locations of measured dissolved calcium concentrations used to interpolate the calcium concentration contours are shown as green dots (*Source:* Wells et al. 2010).

Calcium concentrations in the mainstem Columbia River tend to be lower in summer when temperature is suitable for spawning (Whittier 2010). More research regarding the potential for successful spawning and juvenile survival is needed (IEAB 2013).

It is also unknown if veligers produced by dreissenid mussels that become established in the headwaters of the Columbia would have adequate time to develop to the settling stage during their downstream transit (Claudi and Prescott 2010). Research on the expected time required for newborn mussels to travel from the upper extremities of the Columbia River to Portland may be advisable. A proposed study to answer this question was submitted to the Technology Innovation Program in 2010 (USGS Cook Lab, Lead), but was not funded.

STATUS:

The investigators conducting Technology Innovation project number 276, "*Enhanced monitoring and investigation of the spread and potential impact of aquatic invasive mussels in the Columbia River Basin,*" are conducting research that will help assess the causes and effects of biological invasions in the CRB. Specifically, they are building on existing Washington State University (WSU) and USGS efforts to assess food web effects of AIS in the Columbia and Snake Rivers by documenting the seasonal dynamics of plankton populations and communities.

RECOMMENDATIONS FOR FUTURE WORK:

1. Calculate the expected time required for veligers to travel from the upper extremities of the Columbia River to Portland. This requires better information on larval development rates under the temperature and calcium conditions in the Columbia River.

2. Continue investigating potential for long-term reproductive success, specifically the potential for successful dreissenid spawning and juvenile survival in the CRB.

3. Collect additional calcium and pH data in various parts of the Columbia watershed to better predict dreissenid mussel levels in this environment.

4. Bolster knowledge of risk of establishment by improving understanding of the ability of primary and secondary tributaries to the mainstem Columbia to support quagga and zebra mussels.

5. Investigate the possibility of reservoir management strategies that could be used for the control of established dreissenid populations.

E. Monitoring

The goal of monitoring in the CRB is to detect the earliest stages of dreissenid mussel exposure or infestation so that response planning and budgeting for protective measures can be initiated. Prevention, containment, impact mitigation and control/eradication efforts are most effective when detection occurs at an early stage of infestation.

Monitoring in the CRB is implemented by numerous state and federal agencies. Coordination of monitoring is led by the CRB Team of the 100th Meridian Initiative. Data is collected by PSMFC and the USGS (Cook, Washington), and monitoring data is posted at http://crbans.psmfc.org/monitoring.html. The website includes monitoring activities from 2010–2012 (2013 data will be posted by early 2014).

Monitoring efforts in the CRB has increased significantly in the past 10 years. However, because of the sheer volume of water and number of hydropower and dam facilities, an increase in monitoring should occur to aid in early detection of dreissenids. Most samples of suspected dreissenids are analyzed by cross-polarized light microscopy. Microscopic analysis is time consuming and requires taxonomic expertise. Two newer methods for dreissenid monitoring demonstrate promise in advancing sampling effort include PCR (eDNA) and FlowCam technologies:

> **FlowCAM:** The FlowCAM is a flow-through device with a digital camera, microscope lenses and (in the case of this particular model) polarizing camera. As sample water flows through, particles are dual imaged, producing one black and white digital image and one polarized image to allow visualization of the characteristic "Maltese cross" pattern on zebra and quagga mussel veligers. The image recognition software identifies and counts all veligers, and saves an archive of each individual that is observed. The FlowCAM technology has been in use for nearly 10 years, and the instruments have become well regarded in the field of plankton biology, invasive species monitoring in field samples and ballast water, among others. If successfully applied in the CRB, the use of FlowCAM technology could reduce sample processing time and cost, thus increasing the region's ability to detect zebra and quagga mussels early enough to enact quarantine and control measures by allowing more samples to be collected and processed in any given year. The Technology Innovation Program is currently funding the WSU/USGS project #276, "Enhanced monitoring and investigation of the spread and potential impact of aquatic invasive mussels in the Columbia River Basin." This project is currently testing a FlowCAM unit in the CRB.
>
> **PCR:** Molecular assays based on PCR can amplify DNA in water samples (i.e., environmental DNA or eDNA) and detect the presence of AIS at high levels of sensitivity and specificity. This approach is currently being used to detect Asian carp and zebra and quagga mussel larvae in water systems. There is increasing interest in the development of additional PCR-based assays for these and other AIS. These factors, coupled with the increasing availability of rapid molecular assay systems (kits), are greatly expanding the

use of PCR-based technologies to detect AIS. However the PCR technology has some drawbacks, including false positives and negatives and the need to establish a system for validating assays and accrediting laboratories that report on the presence or absence of AIS (ISAC 2012). Regardless of its drawbacks, the use of PCR assays are increasing nationwide.

There is also a need to prioritize the highest risk water bodies in the CRB (as mentioned earlier in this document, much of the risk is based on calcium concentrations). This prioritization work is currently occurring through USGS/WSU Technology Innovation project number 276. This project is filling gaps in existing early detection efforts for invasive mussels by identifying and sampling in areas at high risk for mussel introduction and establishment, and at locations where monitoring is not currently occurring or where additional efforts would increase detectability. Outcomes include creation of a Geographic Information System (GIS) layer describing all of the river access points on the mainstem Columbia and Snake Rivers and major tributaries, as well as research and information to enhance current understanding of relative use of these river access points. This information is essential for prioritizing the placement of CRB boat cleaning stations.

RECOMMENDATIONS FOR FUTURE WORK:

1. Determine the volume of water that is currently being sampled (veligers) for dreissenids by all agencies in the CRB and determine the appropriate level of sampling to obtain optimal coverage (i.e. probability of detection).

2. Increase monitoring capacity (sampling and analysis) in the CRB.

    - Continue investigating the utility of FlowCam system.

    - Consider the practicality of establishing a CRB-based PCR (eDNA) laboratory.

3. Continue evaluating and prioritizing dreissenid monitoring activities to ensure highest risk water bodies are receiving the majority of sampling effort.

F. Interjurisdictional Coordination

Active coordination among the four Northwest States, the Province of British Columbia, federal agencies, and among state agencies has contributed to regional prevention efforts (IEAB 2013):

States and British Columbia

- Oregon, Washington, and Idaho have state-sanctioned invasive species councils, and British Columbia has an invasive species council.

- Montana does not have a state-sanctioned invasive species council, but does hold annual invasive species summits (next summit is February 5–6, 2014, hosted by MTFWP)

Regional

- The Columbia River Basin Team of the 100th Meridian Initiative serves as the main coordinating entity for the region and includes representatives from the states and federal agencies, the Province of British Columbia, tribal sovereign nations and other entities. The team developed the CRB Rapid Response Plan (CRB Team 2011) and hosts periodic response exercises through the CRB, the most recent being the December 2013 RRWG workshop held in Vancouver, Washington. The group meets twice annually (primarily in the Portland, Oregon area), and also serves to coordinate AIS prevention, research and management activities in the basin.

- The Pacific NorthWest Economic Region (PNWER) is a statutory public/private non-profit created in 1991 by the states of Alaska, Idaho, Oregon, Montana and Washington, the Canadian provinces of British Columbia, Alberta, Saskatchewan, and the Yukon and Northwest Territories. PNWER has an Invasive Species Working Group.

- The Western Regional Panel on Aquatic Nuisance Species was formed by a provision in the National Invasive Species Act of 1996 (P.L. 101-636) to help limit the introduction, spread and impacts of AIS into the western region of North America. This panel meets annually, and its membership includes all state and federal agency AIS coordinators in the western United States.

- The Western Governors Association (WGA) has become more active in AIS issues in the past 2 years, passing resolutions on combatting invasive species and assigning WGA staff to the issue.

National

- The Aquatic Nuisance Species Task Force **(**ANSTF) is an intergovernmental organization dedicated to preventing and controlling aquatic nuisance species, and implementing the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990. The various NANPCA mandates were expanded later with the passage of the National Invasive Species Act (NISA) in 1996. The ANSTF consists of 13 federal agency representatives and 12 ex-officio members, and is co-chaired by the USFWS and NOAA. The ANS Task force coordinates governmental efforts dealing with ANS in the United States, with those of the private sector and other North American interests via regional panels and issue-specific committees and work groups.

- The National Invasive Species Council (NISC) was established by Executive Order (EO) 13112 to ensure that federal programs and activities to prevent and control invasive species are coordinated, effective and efficient. The Invasive Species Advisory Committee (ISAC) is a group of non-federal experts and stakeholders established and mandated by Executive Order (EO) 13112 to provide

advice to the National Invasive Species Council (NISC) on invasive species-related issues.

RECOMMENDATIONS FOR FUTURE WORK:

1. Ensure that AIS prevention efforts at the local, regional and national levels are coordinated and focused on improving efficiencies, streamline processes and information sharing among the numerous consortiums and entities working in the region.

2. Ensure geographic scope of the CRB AIS Team meetings includes entire basin

3. Continue development of a well-maintained and comprehensive website on regional AIS issues to improve information sharing, coordination and collaboration within the CRB.

G. Education and Outreach

Effective aquatic invasive species (AIS) prevention efforts have strategic, sustainable, coordinated vector-focused communications that include information on:

- Identification;
- the importance of reporting sightings;
- the economic, societal and natural resource impacts;
- management and control options; and
- behavioral actions individuals and entities can do to make a difference.

Fostering engagement through a variety of media (e.g., brochures—*Zap the Zebra!*, videos—*Don't Move a Mussel*, boat ramp signs and highway billboards—*Clean, Drain, and Dry*) aimed at specific audiences (e.g., boaters, water body management authorities) or advancing specific messages (e.g., "*Don't Let it Loose"*, and *"Clean, Drain, and Dry"*) is key to the long-term success in achieving AIS prevention effort goals.

Lack of adequate funding, or inefficiencies caused by individual entities/states creating their own messaging and promotional materials, has slowed regional AIS prevention efforts and caused an inefficient use of financial and staff resources. A multi-year regional AIS prevention communication/outreach/education plan would help to efficiently coordinate a set of strategic, vector-focused actions by all CRB (developed and shared with neighboring Canadian provinces).

RECOMMENDATIONS FOR FUTURE WORK:

1. Develop a consistent, multi-year regional AIS prevention communication, outreach, education plan to efficiently coordinate a set of strategic, vector-focused actions by all CRB states (developed and shared with neighboring Canadian provinces).

2. Document products and deliverables from that action plan on a new website that consolidates AIS information for the region.

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