Rapid Response Plan for Zebra Mussels In the Columbia River Basin

A Comprehensive Multi-Agency Strategy to Expeditiously Guide Rapid Response Activities

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Introduction

The zebra mussel (*Dreissena polymorpha*) is a small bivalve mollusk with two matching half shells. Its name is derived from the striped pattern on its shell. The zebra mussel originated in the Balkans, Poland, and the former Soviet Union and was introduced in the mid-1980's into the Laurentian Great Lakes as a result of ballast water discharge. Since its introduction, the zebra mussel has spread to 22 states and two Canadian provinces. It rapidly dispersed throughout the Great Lakes and much of the Mississippi River due to its tremendous reproductive capability (passive drift of large numbers of pelagic, larval veligers allows downstream invasion) and the ability to attach itself to boats navigating from infested waters. Zebra mussels have been found on recreational water craft entering the Columbia River Basin (CRB), but as of the date of this plan, they are not known to be established in any water bodies west of the 100th Meridian (Figure 1).

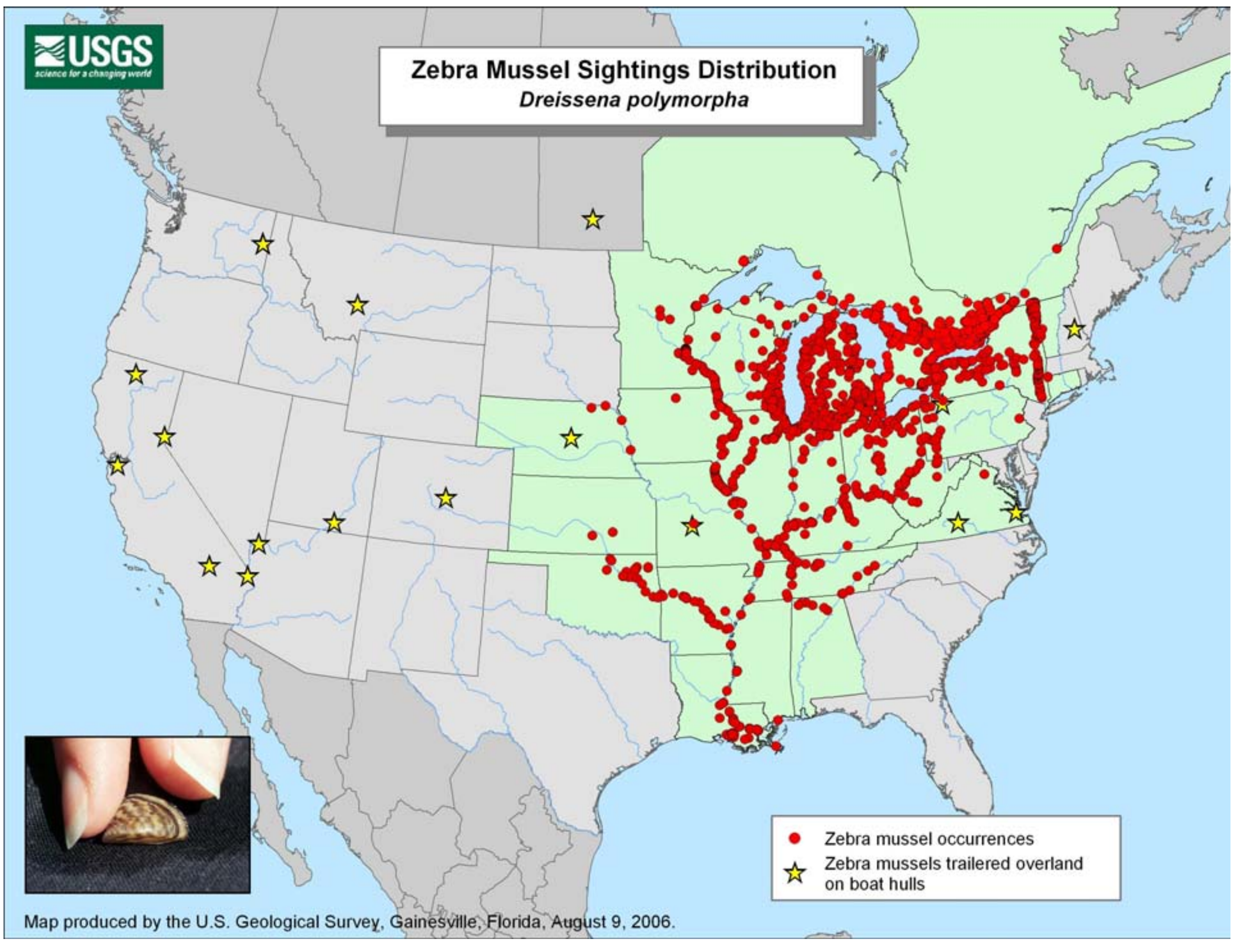

Figure 1: Distribution of zebra mussels in the United States and Canada in 2006. Source: U.S. Geological Survey (http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/).

Zebra mussels continue to expand their range and threaten the CRB. In the past two years, a number of events have raised concerns about the potential for an invasion:

- **Summer 2003:** Zebra mussel veligers were discovered in the middle Missouri River in Northeast Nebraska.
- **May 2004:** A boat from Tennessee was intercepted just east of Spokane with live zebra mussels.
- **June 2004:** A houseboat from Kentucky was intercepted at Lake Mead.
- **March 2005:** A zebra mussel infested boat was intercepted in the Gallatin Valley, Montana.
- **October 2005**: a jar of freshly dead zebra mussels was left on the doorstep of the Charles M. Russell Wildlife Center near Fort Peck Reservoir (Jordan, Montana).
- Over 100 additional interceptions of watercraft with attached zebra mussels in western states during 2004-2006.

Zebra mussels attach to any stable substrate such as pilings, pipes, rock, cement, steel, rope, crayfish, other bivalves, aquatic plants, and each other, forming dense colonies.

Drake and Bossenbroek (2004) identify the Columbia River as being at high risk for an invasion. Zebra mussel densities within the CRB could vary widely depending on water chemistry, food availability, and breeding population. After their initial introduction, zebra mussel populations can rapidly increase by orders of magnitude, and then similarly decrease. Eurasian zebra mussel population densities range up to 40,000 mussels per square meter (Neumann et al. 1993). Under ideal conditions in the Laurentian Great Lakes, zebra mussel densities reach 700,000 – 800,000 per square meter (Kovalak et al. 1993). In the lower Mississippi River, where the zebra mussel has been introduced, densities of 400,000 per square meter have been reported (Kraft 1995). The Mississippi has an ideal environment for zebra mussels, in part because food resources are abundant (Kraft 1995).

While Columbia River water quality parameters are favorable to zebra mussel colonization (Athearn 1999), the Columbia River's lower plankton densities in comparison to the Mississippi or Great Lakes, may limit zebra mussel population densities.

The environmental impact of zebra mussels upon lakes and rivers can be profound. Zebra mussels compete effectively with many native species and may completely replace native mussels. For example, phytoplankton biomass declined 85% following mussel invasion in the Hudson River (Caraco *et al.* 1997). Some species of waterfowl (e.g. lesser scaup, *Aythya affinis*) and fish (e.g. freshwater drum, *Aplodinotus grunniens)* eat zebra mussels, but have not been shown to significantly control their numbers.

The introduction of zebra mussels into the CRB, which drains 258,500 square miles in seven Western states and Canada, could not only threaten native species, (particularly salmon and trout), but also industrial, agricultural, recreational, navigation, and subsistence use of the infested waters. The economic costs associated with zebra mussels can also be significant when water users and water extractors must contend with mussels fouling facilities and equipment. A variety of studies have reported economic impacts of zebra mussels in the eastern United States, such as a recent survey that estimates $268 million in zebra mussel-related impacts just to drinking water and power plant facilities from 1989 to 2004 (Connelly et. al., 2006).

The economic and social impacts of zebra mussels to the significant hydropower system on the Columbia and Snake Rivers is of particular concern. If zebra mussels invaded the CRB, they could affect all submerged components and conduits of this system, including fish passage facilities, navigation locks, raw water distribution systems for turbine cooling, fire suppression and irrigation, trash racks, diffuser gratings, and drains (see Appendix H). The Bonneville Power Administration commissioned a study of the costs associated with zebra mussel control on hydro-power facilities in the Columbia River (Phillips et al. 2005). The study found that:

> The one-time cost for installing zebra mussel control systems at hydroelectric projects could range from the hundreds of thousands of dollars to over a million dollars per facility. 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). Removal, painting, sandblasting and installation could potentially double antifouling paint treatment costs.

The University of Notre Dame, with funding from the National Oceanic and Atmospheric Administration and the Western Regional Panel of the Aquatic Nuisance Species Task Force, currently is working to further characterize a broader suite of economic impacts from zebra mussels in the Columbia Basin and other Western rivers based on likely ecological range.

Numerous western states have funded active zebra mussel prevention and monitoring programs for a decade or more. In the CRB, Oregon, Washington, Montana all have federally approved and funded aquatic nuisance species (ANS) programs. Regionally, the 100th Meridian Initiative is a cooperative effort between state, provincial, and federal agencies to 1) prevent the spread of zebra mussels and other ANS into the western United States and 2) monitor and control zebra mussels and other ANS if detected in these areas (USFWS 2001). Within the 100th Meridian Initiative, there exists an active CRB Team, whose membership includes state, federal, Tribal, and university ANS managers and researchers. Most of the initiative's activities are centered on monitoring and education. The 100th Meridian Initiative has proven highly effective in enhancing early detection capacity and reducing the risk of introductions. However, the initiative and the CRB group are not set up to coordinate a rapid response to a zebra mussel invasion at this time, as they lack the regulatory authority to implement a prompt response to an invasion. It is therefore essential to develop the capacity for rapid eradication or containment efforts should an introduction occur.

Although an attempt to eradicate a new zebra mussel infestation presents significant challenges, there is at least one documented success story. In 2002, zebra mussels were confirmed in Millbrook Quarry as the first introduction in Virginia. The 12-acre quarry is located on property under private ownership. The Virginia Department of Game and Inland Fisheries led an effort to eradicate this population. Over a three-week period in early 2006, the water body was treated with 174,000 gallons of potassium chloride solution over a 3-week period from January 31 to February 17, 2006. Potassium concentrations were measured weekly throughout the quarry and in adjacent surface waters to ensure a target concentration of 100 milligrams of potassium per liter of water (below the level that would have human health or significant ecological impacts, but over twice the minimum concentration needed to kill zebra mussels). No potassium leakage from the quarry into adjacent waters was detected.

Monitoring results demonstrated that lethal potassium concentrations were achieved at various depths. Several weeks after treatment ended, four independent methods were also used to confirm zebra mussel eradication. First, more than 1,000 mussels were sampled from rocks at numerous sites around the quarry; none were alive. Divers also visually inspected the quarry and could not find live zebra mussels. An extensive video survey also was conducted using a robotic camera system, documenting dead zebra mussels. Finally, 80 sets of live zebra mussels (100 per set) were placed at various locations and depths within the quarry. After one month of exposure to the treated quarry water, mortality of these test mussels was 100% (as opposed to zero mortality of a control set placed in untreated water). Other aquatic life in the quarry (including turtles, fish, and aquatic insects) appear to be thriving after the treatment. As of June 2006, no additional zebra mussels have been found in the quarry. It is important to note that this case involved infestation in a small, contained water body. Attempting to eradicate zebra mussels in a large river system presents a very different set of challenges.

As demonstrated time and again for oil spills, forest fires, and other environmental emergencies, effective rapid response depends on effective contingency planning. This zebra mussel rapid response plan for the Columbia Basin reflects strategies, models, and activities from a variety of other contingency plans. In particular, it draws from the *Model Rapid Response Plan* created in 2003 by the Western Regional Panel (WRP) of the ANS Task Force. The WRP model plan used recent examples of invasions to describe lessons learned and to discuss the elements which influence the success or failure of a response. It describes a two-tiered model system which is organized within state government. It recommends a statewide invasive species council, a structure for implementing projects, and adequate emergency funding.

Scope and Purpose

Prevention remains the first priority for addressing the CRB zebra mussel risk, including preventing contaminated watercraft from entering uncontaminated water bodies. However, if prevention efforts fail and live zebra mussels invade a water body within the CRB, a plan is needed to ensure an effective inter-jurisdictional response. This plan is not intended to guide interception of contaminated watercraft prior to launching. **The goal of the plan is to serve as a roadmap that actively guides rapid response activities if zebra mussels are detected in CRB waters.** It functions as an operational plan, not a strategic plan. Therefore, while the plan may suggest a number of further planning tasks needed to enhance preparedness, the activities outlined in this document focus on actions that would **follow** a reported zebra mussel introduction. Note that “rapid” is subject to interpretation, but for the purposes of this plan, initial stages of rapid response are measured in hours and days, not weeks.

Implementation of the plan must be accompanied by managers aggressively responding to the particular circumstances of a zebra mussel infestation. Some of the tasks identified in the plan are already ongoing, while others will need to be implemented expeditiously following review and approval. Ideally, this plan will prompt improvements in response timing, technology, organizational development, permitting efficiencies, funding mechanisms, outreach strategies, and other tools that in turn will allow the plan to evolve further over time. In particular, agencies guided by the plan will need to develop letters of agreement, Memoranda of Understanding (MOU), or similar documents to solidify their commitment to roles, responsibilities, and policies laid out in the plan. These documents would not necessarily legally mandate an agency to undertake certain response actions, nor require regulatory changes unless deemed necessary by each individual agency. Similar agreements can formalize partnerships with private businesses, landowners, etc. A sample MOU is under development (see Appendix G).

As with many contingency plans, this plan should be considered within a tiered context. A rapid response plan for zebra mussels in the CRB is similar to oil spill geographic response plans (GRPs) developed for various subregions within the Pacific Northwest, including segments of the Columbia and Snake Rivers. These GRPs in turn relate to the broader Northwest Area Contingency Plan, individual state response plans, and individual facility response plans (more information on these plans is available at http://www.rrt10nwac.com/nwacp_document.htm). Other rapid response models include those used by the National Interagency Fire Center. Although more work needs to be done, some analogues for these other levels of zebra mussel response planning exist. For example, the state of Washington has developed a general ANS early detection/rapid response plan. A zebra mussel response plan specific to the Bonneville Lock and Dam project under the U.S. Army Corps of Engineers is included as Appendix

H. The purpose of the Bonneville Hydroelectric Project Rapid Response Plan is to provide facility-specific project information to support rapid response that protects project infrastructure in the event of an introduction of zebra mussels. Though specific to Bonneville Hydroelectric Project, Appendix H should provide sufficient general information that other projects could modify it to cover their plants with minimal additional effort.

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Rapid Response Activities

Rapid response to zebra mussels in the CRB fall into the following 10 categories:

1. Verify Reported Detection
2. Make Initial Notifications to All Relevant Managers
3. Define Initial Extent of Colonization
4. Define Roles and Responsibilities; Set Up a Coordination Mechanism
5. Establish External Communications System
6. Organize Resources (Personnel, Equipment, Funds, etc.)
7. Initiate Quarantine/Pathway Management to Avoid Further Spread
8. Launch Available/Relevant Control Actions
9. Institute Long-Term Monitoring
10. Evaluation of the response and the plan

These are detailed below and also summarized in a checklist found in Appendix A. **Note that these activities are not necessarily sequential; many may be implemented simultaneously**. In particular, a quick and effective management decision-making framework will need to immediately evolve, probably centered on Activity 4. Without this decision-making infrastructure, these ten critical work activities and regional response capacity will be much less effective

Rapid Response Activity 1: Verify Reported Detection

Who: The individual that receives and accepts responsibility for handling the initial report in coordination with the state, tribal, provincial, and/or federal agency where the initial sighting of mussels occurs.

What: The objectives are to confirm the veracity of the report, determine the condition (age, maturity, spawning status, etc.) of the zebra mussels, and ensure that everyone is handling reports consistently and judiciously across a broad geographic area.

How:

1. Interview the reporter(s) to validate detection by:
   - Recording details of the location such as name of the affected water body, landmarks, highway mile, and other (GPS if possible) where the suspect mussels were found.

- Collecting contact information from the reporter(s).
- Securing an estimate of the number, density, extent of the mussel colony(ies) found.
- Obtaining a digital or other photograph (with scale indicator), if possible.
- Securing a sample of the mussels, if possible.
- Documenting the date and time of sighting(s).
- Noting other relevant conditions (access limitations, etc.)

2. Validate identification as soon as possible via examination of a physical sample.

- When feasible, arrange for a site visit by at least one recognized expert (preferably a small team) – see Appendix B.
- If recognized experts cannot feasibly reach the site within 48 hours, arrange to have samples and other evidence (e.g., photographs) sent via Express Mail Service to the most accessible recognized expert listed in Appendix B.
- Prior to shipping samples, obtain guidelines from recognized experts (and use any existing protocols) regarding handling of the sample, desired quantity, where and how to deliver the sample, etc.

Note – as a precautionary principle, until proven otherwise, consider the likelihood that zebra mussels have been in the system more than one year, that they have reproduced, that they have dispersed downstream, and that their source is from a population upstream.

Rapid Response Activity 2: Make Initial Notifications

Who: The individual/organization listed in Appendix B that initially confirms zebra mussel identification (with assistance from agencies in relevant jurisdictions); follow-up notifications by Priority 1 contacts listed in Appendix C.

What: The objectives are to ensure all parties that may affect a response decision are quickly engaged and to also rapidly inform all other interested parties.

How:

1. Within the first 24 hours or as soon as practical after a physical sample is visually confirmed to be a zebra mussel by a recognized expert listed in Appendix B, the expert (with assistance from agencies in relevant jurisdictions) will notify all primary management contacts listed in Appendix C. **It is critical that this notification list be updated, and preferably tested, at least annually**.

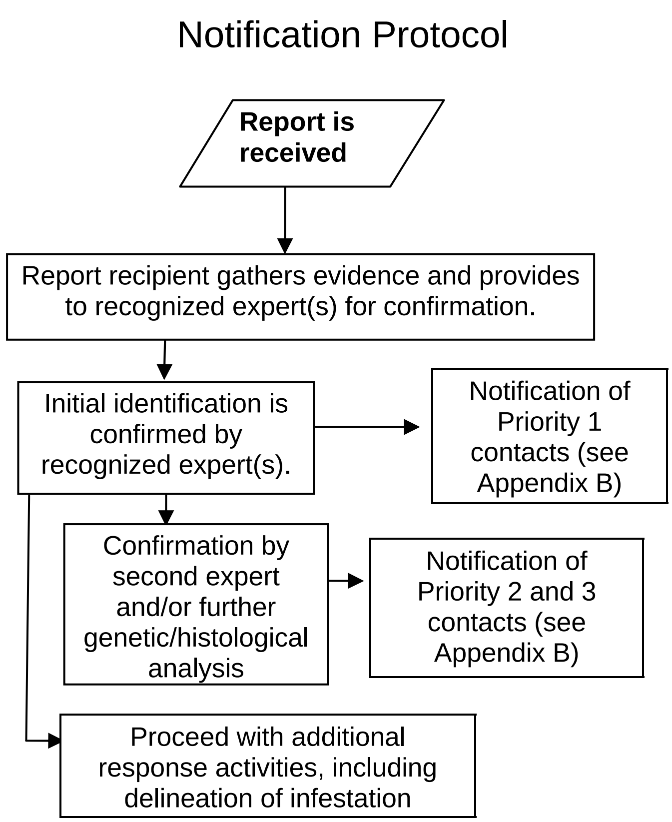
   Note that for many organizations, only primary contacts will be notified. Those primary contacts will then be responsible for further internal notification **within the jurisdiction** of their organization (i.e., primary contact for a state only would be responsible for contacting other key state government officials within their state; primary contact for a federal agency would be responsible for contacting key officials within their agency; etc.). This will require these primary contacts to develop and maintain their associated internal notification lists). See Appendix C for more details.

2. Secure verification of notifications to confirm that parties on the contact list did, in fact, receive notification (e.g., Internet list server response confirmation requirement, phone list call-backs, etc.).

3. While proceeding with subsequent response activities described below, obtain secondary visual confirmation of zebra mussel identification via a different expert listed in Appendix B. Also obtain definitive confirmation based on genetic or histological analysis.

This process is summarized in Figure 2. Note that general public/media notification, which occurs in Activities 5, 7 and 8 via a joint information center, should not occur until secondary confirmation is achieved.

Figure 2



Rapid Response Activity 3: Define Initial Extent of Colonization

Who: The appropriate state or Canadian agency where the initial sighting (s) of mussels occurs in partnership with other agencies and organizations.

What: The objective is to rapidly provide information to guide subsequent management decisions, including survey design.

How:

1. Determine potential geographic extent of infestation, including upstream and downstream areas and connected water bodies. Also survey nearby water bodies with vulnerability to the same vectors (using information from boater surveys where available to determine high traffic areas). These efforts should follow existing regional or national protocols. Note that while dye studies and other hydrographic research can support prediction of likely spread from the infestation, experience in other regions has led to applying simpler methods such as interviewing field personnel to determine potential water flow dispersal of zebra mussel veligers.

2. Determine demography of infestation (e.g., age structure). These efforts should follow existing regional or national protocols. Potential methodologies include sampling fixed and temporary hard substrates, shoreline surveys, and plankton sampling. Where possible, surveys should assess maturity and spawning condition of mussels at the infestation site(s). Plankton sampling should involve sufficient water volume to detect low veliger concentrations. Since veligers may only be in the water for a short period of time, plankton sampling and identification must have a quick turnaround time (no more than a week), so that further sampling can occur swiftly and in a coordinated fashion that ensures proper geographic coverage.

3. Identify any potential facilities (e.g., hydropower, fish hatcheries, irrigation systems, etc.) that could be affected. See Appendix H.

4. Identify potential sites that may be colonized.

5. Ensure that surveys are completed and that results are reported through a common website such as http://100thmeridian.org.

Rapid Response Activity 4: Define Roles and Responsibilities; Set-Up a Coordination Mechanism

Who: Lead coordinating agency, as defined below.

What: The objective is to activate a **predetermined** response management system that expedites decision-making, information sharing, avoids duplication, and minimizes authority conflicts, while preserving flexibility for adaptive management. **Any existing memoranda of agreement or other agreement documents developed in association with this plan should be consulted to guide the below steps.**

How:

1. The appropriate state or Canadian agency associated with the initial sighting of zebra mussels convenes a meeting of all relevant managers and these cooperators select a lead coordinator for coordinating management activities (see Table 1). At a minimum, this meeting should involve all organizations listed in the Priority 1 table of Appendix C that have jurisdiction within the infestation area (or are likely to be affected downstream. Note that this lead coordinator will not be the primary decision-maker or have veto power regarding response strategies; he or she simply will serve as a primary point-of-contact for resolving coordination and logistical problems. Response actions within the boundary of lands, waters, or structures owned/administered by a particular individual, organization, or jurisdiction will be overseen by that owner/administrator. For infestations confined to a single state, in the event a consensus decision regarding lead coordinator can not be reached quickly, the state ANS coordinator will serve as the default lead coordinator unless the relevant authorities reach agreement on an alternative. For a multi-state infestation within the United States where there is no initial consensus on a lead coordinator, this default role will fall to the appropriate U.S. Fish and Wildlife Service Regional ANS Coordinator unless the relevant authorities reach agreement on an alternative.

   The lead coordinator(s) will:

   - Coordinate notification operations
   - Facilitate creation of a management team comprised of a lead representative of each local, tribal, state, provincial, and/or federal government that has legal authority over the response.
   - Develop a unified command structure (e.g., operational subgroups, internal reporting system, etc.) under the management team.
   - Represent (i.e., be the spokesperson for) the management team.
   - Facilitate agreement on decision rules.
     - o e.g., Intervention decisions made by consensus.
     - o e.g., Coordination decisions made by ‘cascading’ through the ‘tiered’ list of affected interests as decided by agency director, Governor, or delegated authority.
   - Facilitate development of response priorities

Table 1

Partial List of Agencies and Organizations with Invasive Species Management/Coordination Responsibilities in the CRB

- Washington Department of Fish and Wildlife
- Idaho Department of Fish and Game
- Montana Department of Fish, Wildlife, and Parks
- Oregon Department of Fish and Wildlife
- Portland State University, Center for Lakes and Reservoirs
- Columbia River Intertribal Fish Commission
- Individual Columbia River non-treaty tribes (Colville, Wampum, Lower Columbia River tribes)
- Mid-Columbia River Public Utility Districts
- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service
- National Park Service
- U.S. Geological Survey
- U.S. Bureau of Reclamation
- Bonneville Power Administration
- NOAA Fisheries
- U.S. Environmental Protection Agency
- Department of Fisheries and Oceans, Canada
- State aquatic invasive species committees
- Western Regional Panel on Aquatic Nuisance Species
- Pacific States Marine Fisheries Commission
- 100th Meridian Initiative Columbia River Basin Team
- Oregon and Washington Sea Grant Programs

2. These above actions should take into account roles/relationships/inter-agency agreements among:

- All affected states: e.g., Governor, state agencies, ANS Coordinator.
- Federal agencies: Fish and Wildlife Service, Corps of Engineers, EPA, NOAA, etc.
- Canada: Fisheries and Ocean Canada, Provincial Environmental Agencies, etc.
- Tribes.
- Local governments.
- Other interested parties, such as irrigation districts, marinas, etc.

3. The local response team should draw upon technical experts from outside the region to help advise response operations.

Rapid Response Activity 5: Establish External Communications System

Who: The Lead Coordinator identified in Activity 4 above.

What: Develop Joint Information Center to ensure consistent and effective communication to interested external stakeholders, including the media and public.

How:

1. Notification and education of affected landowners, and associated efforts to gain their written permission to access property for response activities.

2. Notification and education of potentially-affected water users and water-rights holders.

3. Development of public information strategy, press packets, press release process, and press conferences. See sample press release included as Attachment 3 in Appendix H.

4. Development and implementation of general public education and outreach. Since there are a variety of educational materials between regions and states, assure coordination and perhaps agreement on materials that can be used region-wide.

Rapid Response Activity 6: Organize Resources

Who: The Lead Coordinator identified in Activity 4 above in partnership with all other organizations involved in the response.

What: The objective is to provide sufficient resources to initiate control actions and associated activities (including acquisition of required permits).

How:

1. Develop estimates for staffing needs, facilities and equipment, and funding.

2. Identify potential sources for staffing, facilities, equipment, and funds.

3. Secure commitments for needed staff, facilities and equipment, and funds.

4. Ensure mechanism for dispersal of funds is in place, and when the funds are needed, flow of dollars occurs expeditiously.

Rapid Response Activity 7: Initiate Quarantine/Pathway Management to Avoid Further Spread

Who: Management Team/Lead Coordinator.

What: Minimize all vectors that might further spread the original infestation.

How:

1. Evaluate risks, dispersal vectors (including movement by humans, fish and wildlife, water traffic, water flow, and other physical processes). Assume veligers are present until proven otherwise and assume measures are needed to prevent release of veligers as well as movement of adults.

2. Restrict dispersal pathways, where feasible, including:

    - Quarantine infested water bodies as needed to prevent spread by watercraft, following any existing protocols.
    - Assess the likely movement of boats that recently used the infested water body to identify inspection needs in other water bodies.
    - Establish wash and inspection requirements on boats and equipment, with assistance if warranted.
    - If feasible, determine and eliminate the likely source of zebra mussel inoculation (e.g., infested boat) as warranted.
    - Begin a post haul-out inspection of boats and equipment in the areas where mussels were found.
    - Begin a pre-launch inspection program for all boats and equipment in places where boats and equipment from a contaminated area are likely to be launched next.
    - Ensure that zebra mussel "alert" signs are adequately deployed.
    - Begin outreach to alert prior users of these waters of the risks their boats and equipment create for other water bodies.
    - Consider and implement any needed prevention of overland veliger or adult mussel transport to other water bodies.
    - Develop and implement Hazard Analysis and Critical Control Point (HACCP) plans to ensure that local, state, tribal or federal government response personnel do not further spread the original infestation.
    - Work with Joint Information Center (see Activity 5) to design and implement educational outreach programs using print, electronic media and other avenues, with an emphasis on raw water users.
    - Stop or slow water release to potentially uninfested sites.
    - Draw water from below thermocline.
    - Install physical barriers.

Rapid Response Activity 8: Initiate Available/Relevant Control Measures

Who: Management Team/Lead Coordinator.

What: Evaluate management options, and then proceed with either eradication efforts or containment/mitigation activities.

How:

1. Decide if eradication is possible based on rapid analysis of population dynamics and pathways of spread. Consider the following:

   - Anticipated cost of eradication effort relative to available funding
   - Type of water body – contained lake, mainstem reservoir, tributary reservoir, small stream, large river, estuary, or water diversion facility.
   - Type of substrate – e.g., rocks that allow zebra mussel attachment on their undersides where chemicals may not reach them.
   - Extent of population distribution – isolated vs. widespread coupled with *a priori* assumptions about the spread of mussels before detection.
   - Life stage(s) present (default assumption is both veligers and adults).
   - Time of year in relation to spawning season.
   - Is spawning occurring now or at least possible based on current water temperature (i.e., 12 °C or greater)?
   - When is the likely spawning season based on predicted temperature conditions?
   - How do mean monthly temperature patterns for the water body relate to zebra mussel spawning requirements?
   - Amount of water in reservoir or waterway.
   - Does the reservoir need to be drawn down before treatment?
   - How far can the reservoir be drawn down?
   - Is river flow low enough for effective treatment?
   - Circulation patterns in water body.
   - Spreading pattern of population within the water body.
   - Inflow rates and sources.
   - If drawdown needs to occur, what is the feasibility given input source(s)?
   - Rate of outflow and distance of veliger dispersal.
   - Do flow patterns help or hinder eradication options?
   - Presence of state or federally listed threatened or endangered species.
   - Special status of water body, including:
     1. Water use designation (e.g., drinking water).
     2. ‘Wild and scenic’ designation.
     3. Wilderness area.
     4. Potential impact to cultural resources.
     5. Department of Defense or other restricted access areas
     6. Tribal lands

7. Endangered Species Act critical habitat
8. Presence of marine mammals covered by Marine Mammal Protection Act
9. Clean Water Act 303(d) listing
10. Beneficial Uses of water bodies

2. If eradication is attempted, select appropriate method(s) - see Appendices D-F.

3. If eradication is not possible, develop control objectives and select/design appropriate control measures - see Appendices D and E.

4. Obtain relevant permits and regulatory agency concurrence (see Table 2 for a partial list).

- Determine the permits and other regulatory reviews required for chosen eradication methods, including any applicable emergency provisions.
- Begin with any existing permits and/or templates for required permits.
- Assign lead person from each regulatory agency to facilitate permit approval in a timely manner within their respective agency.
- Obtain a FIFRA Federal Crisis Exemption (e.g., 40 C.F.R. PART 166) if the known or accepted methods of eradication are not currently permitted.
- Determine if an environmental impact statement or environmental assessment is required and if so, begin that work.
- NPDES (Section 402)
- NEPA (using template for environmental assessments where available)
- Initiate Endangered Species Act Section 7 consultations if needed by contacting appropriate U.S. Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration (NOAA) field offices.

USFWS ESA Section 7 consultation contacts in:
Oregon: 503-231-6179
Idaho: 208-334-1931
Washington: 360-534-9330

NOAA Fisheries ESA Section 7 consultation contacts in:
Oregon: 503-230-5425/5428
Idaho: 208-378-5734
Washington: 360-526-6604

5. Implement eradication or control strategies

- Lead Coordinator facilitates implementation of operations plan developed by management team
- Agencies collaborate to coordinate and deploy field resources

- Establish schedule for frequent management team meetings to resolve operational issues that cross jurisdictional interests.

Table 2

Partial List of State/Federal Permits and Regulatory Reviews Likely To Apply to Eradication of Zebra Mussels in the CRB

- Corps of Engineers Section 10 permit for discharge of dredge/fill material
- Clean Water Act Section 404 permit for work in navigable waters from Corps of Engineers
- Clean Water Act National Pollutant Discharge Elimination System (Section 402) permit (or modification of existing general permit) from Environmental Protection Agency or delegated state
- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) – particularly Section 18 emergency exemption
- National Environmental Policy Act reviews, such as Environmental Impact Statements (triggered by other federal authorizations) – includes provisions for emergency consultations+
- Endangered Species Act Section 7 consultations by U.S. Fish and Wildlife Service and/or National Oceanic and Atmospheric Administration consultations (triggered by other federal authorizations) – emergency
- State aquatic land use authorization
- State water diversion/water-based construction permits and project approvals
- State archaeological excavation permit
- State hazardous chemical storage and reporting requirements

Rapid Response Activity 9: Institute Long-Term Monitoring

Who: Management Team/Lead Coordinator.

What: Provide for data for adaptive management and long-term evaluation efforts.

How:

1. Design a monitoring program to evaluate the status of the zebra mussel populations, emphasizing veliger sampling. Monitoring activities should be carried out in coordination with other field operations, such as environmental monitoring to meet permit and other regulatory compliance requirements (e.g. National Pollutant Elimination Discharge System [NPDES]).

2. Disseminate findings through an easily accessible, consolidated, coordinated real-time database and list serve (e.g., via 100th Meridian Initiative website)

Rapid Response Activity 10: Evaluation

Who: Management Team/Lead Coordinator.

What: Allow for adaptive management by ensuring feedback on the efficacy of response actions and the effectiveness of the Rapid Response Plan; enhance long-term preparedness for response to other aquatic invasive species introductions.

How:

1. Conduct a follow-up evaluation of response organizations and other interest groups to identify opportunities for improving rapid response capacity. Disseminate "lessons learned" to other interested organizations (e.g., regional ANS panels).

2. Revise the Rapid Response Plan and associated documents/guidelines based on evaluation and long-term monitoring results.

3. As resources allow, develop and implement a research plan that evaluates the associated ecological and economic impacts of the invasion, the effectiveness of management interventions, and negative consequences of management interventions (beyond that required by permits).

4. Determine the need for long-term funding for the current management effort and seek this funding as warranted.

- Meet with state and federal legislators to map out a regionally coordinated long term funding strategy

Rapid Response Scenarios

The following scenarios are provided to illustrate how the above plan guidance might be carried out in a real incident. They are not intended to encompass all likely incidents of a zebra mussel introduction in the CRB. They also are not intended to provide a script for carrying out response actions for actual introductions that resemble the scenario.

Scenario 1: Veligers found in a CRB reservoir but no adults detected

2-3 page narrative and/or chart to be developed which describes how verification, notification, surveillance, etc. would proceed, with focus on verification and surveillance

Scenario 2: Reproducing adult zebra mussels found growing on a mainstem hydropower system structure

2-3 page narrative and/or chart to be developed which describes how verification, notification, surveillance, etc. would proceed, with focus on organization development leading to eradication decision.

Scenario 3: Adults found on boats in a protected marina in a CRB waterbody connected to mainstem; no mussels or veligers found outside marina

2-3 page narrative and/or chart to be developed which describes how verification, notification, surveillance, etc. would proceed, with focus on containment and associated pathway management.

Scenario 4: Live adult zebra mussels found in an isolated water body within the CRB (e.g., Blue Lake in Grant County, Washington)

2-3 page narrative and/or chart to be developed which describes how verification, notification, surveillance, etc. would proceed, with focus on eradication effort.

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Appendix A: Response Checklist

Note: this list is not intended to indicate sequential order of completion

- ☐ Gather information on sighting from original reporter; verify it's not a hoax
- ☐ Obtain verification of physical sample by recognized expert(s)
- ☐ Once report is confirmed by recognized expert(s), notify primary response contacts
- ☐ Verify all critical notifications were completed
- ☐ Once secondary confirmation occurs, notify other interested parties
- ☐ Determine geographic extent of infestation
- ☐ Survey nearby water bodies with vulnerability to the same vectors
- ☐ Evaluate/collect data on density, age, size demography of infestation .
- ☐ Identify potentially-affected facilities.
- ☐ Convene initial meeting of all relevant response organizations
- ☐ Select a lead coordinator for coordinating management activities.
- ☐ Establish a management team and unified command structure
- ☐ Establish an external communications system (media briefings, etc.)
- ☐ Develop estimates for staffing needs, facilities and equipment, and funding.
- ☐ Identify potential sources for staffing, facilities, equipment, and funds.
- ☐ Secure commitments for needed staff, facilities and equipment, and funds.
- ☐ Evaluate vectors for subsequent dispersal of initial infestation.
- ☐ Based on risk evaluation, restrict dispersal pathways where feasible.
- ☐ Decide if eradication is possible based on rapid analysis of population dynamics and pathways of spread.
- ☐ If eradication is attempted, select appropriate method(s).
- ☐ If eradication is not possible, develop control objectives and select/design appropriate control measures.
- ☐ Obtain relevant permits and regulatory agency concurrence.
- ☐ Design and implement public and media outreach associated with eradication/control plans.
- ☐ Implement eradication or control strategies
- ☐ Design a monitoring program to evaluate:
    1. zebra mussel populations,
    2. associated ecological and economic impacts,
    3. effectiveness of management interventions, and
    4. negative consequences of management interventions (including any required compliance monitoring for permit obligations).
- ☐ Carry out monitoring activities in coordination with other field operations
- ☐ Disseminate findings on easily accessible coordinated database
- ☐ Revise existing plans/guidelines to make improvements.
- ☐ Determine the need, amount, and sources for long-term funding.

Appendix B: Recognized Experts For Confirming Zebra Mussel Identification

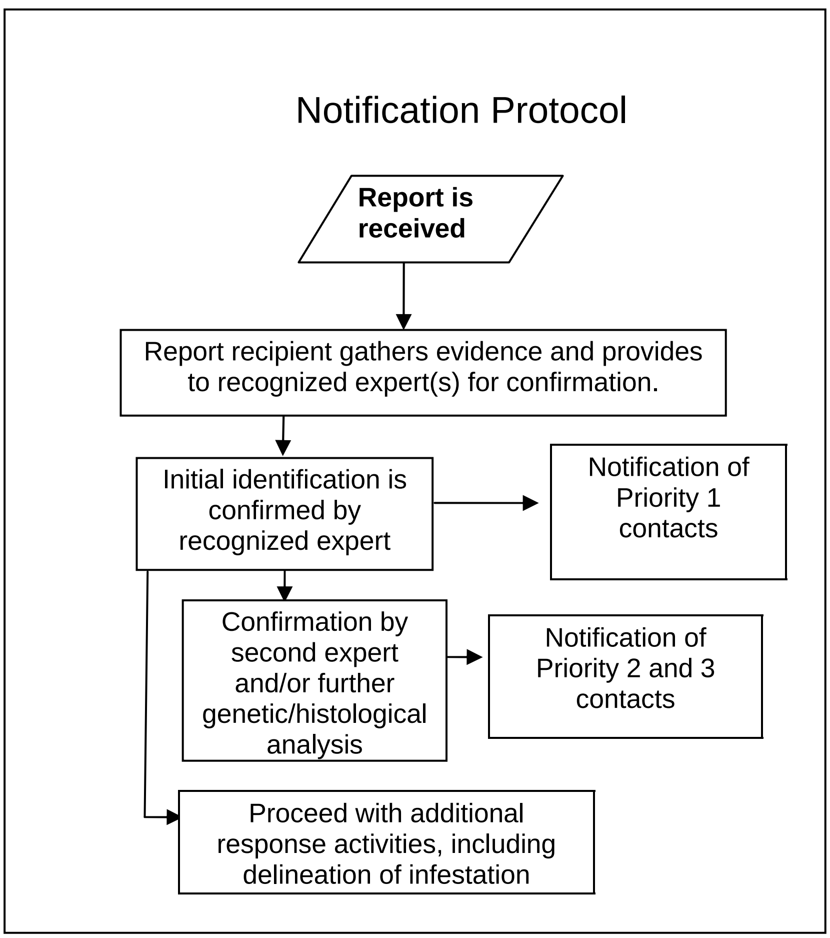
Name and/or Position	Affiliation	Life stage expertise	Phone	Email	Overnight mail shipping address	Notes
ANS Coordinator	**Portland State University, Center for Lakes and Reservoirs**	**Veligers, Adults**	**See Appendix C**	**See Appendix C**		
ANS Coordinator	**Washington Department of Fish and Wildlife**	**Adults**	**See Appendix C**	**See Appendix C**		
ANS Coordinator	**Idaho Department of Fish and Game**	**Adults**	**See Appendix C**	**See Appendix C**		
ANS Coordinator	**Montana Fish, Wildlife, and Parks**	**Veligers, Adults**	**See Appendix C**	**See Appendix C**		
ANS Coordinator	**U.S. Fish and Wildlife Service, Pacific Region**	**Adults**	**See Appendix C**	**See Appendix C**		
ANS Coordinator	**U.S. Fish and Wildlife Service, Western Washington Field Office**	**Adults**	**See Appendix C**	**See Appendix C**		
Jeff Herod, ANS Coordinator	**U.S. Fish and Wildlife Service, Stockton Field Office**	**Veligers, Adults**	**209-946-6400, x321**	**jeffrey_herod@fws.gov**		
Tina Proctor, ANS Coordinator	**U.S. Fish and Wildlife Service, Mountain-Prairie Region**	**Adults**	**303-236-4515**	**bettina_proctor@fws.gov**		
Linda Beck, ANS Coordinator	**U.S. Fish and Wildlife Service, Bozeman Fish Technology Center**	**Veligers, Adults**	**406-994-9947**	**linda_beck@fws.gov**		
Bob Pitman, ANS Coordinator	**U.S. Fish and Wildlife Service, Southwest Region**	**Adults**	**505-248-6471**	**bob_pitman@fws.gov**		

Appendix B (continued): Recognized Experts For Confirming Zebra Mussel Identification

Name and/or Position	Affiliation	Life stage expertise	Phone/Fax	Email	Overnight mail shipping address	Notes
David Britton, Asst. ANS Coordinator	**U.S. Fish and Wildlife Service, Southwest Region**	**Adults**	**817-272-3714**	**david_britton@fws.gov**		
Mike Hoff, ANS Coordinator	**U.S. Fish and Wildlife Service, Great Lakes Region**	**Adults**	**612-713-5114**	**michael_hoff@fws.gov**		
ANS Coordinator	**U.S. Geological Survey, Western Fisheries Research Center**	**Adults**	**See Appendix C**	**See Appendix C**		
Zebra Mussel Information System Coordinator	**U.S. Army Corps of Engineers, Engineer Research and Development Center**	**Veligers, Adults**				
Invasive Species Coordinator	**Environmental Protection Agency, Region 10**	**Adults**	**See Appendix C**	**See Appendix C**		
ANS Coordinator	**Columbia River Intertribal Fish Commission**	**Adults**	**See Appendix C**	**See Appendix C**		
ANS Coordinator	**Pacific States Marine Fisheries Commission**	**Adults**	**See Appendix C**	**See Appendix C**		
Sam Chan, ANS Coordinator	**Oregon Sea Grant**	**Adults**	**503-679-4828**	**samuel.chan@ oregonstate.edu**		
ANS Coordinator	**California Sea Grant**	**Adults**				
ANS Coordinator	**Minnesota Sea Grant**	**Adults**				
Director	**Center for Biological Macrofouling Research, University of Texas-Arlington**	**Veligers, Adults**				

Appendix C: Notification List/Procedures

The following notification list is intended to guide the emergency phase of response to a report of zebra mussels in the Columbia River Basin. For each jurisdiction or stakeholder group, a primary and alternate contact are provided. These contacts are in turn responsible for any internal contacts within their organization that are not included in this list. Primary contacts (or their alternate) designated as "Priority 1" are to be contacted immediately by phone, fax, and email as soon as a recognized expert has confirmed identification of reported zebra mussels. It is essential to confirm that the primary contact or their alternate has been alerted. Contacts designated as "Priority 2" and "3" are to be contacted by phone, email, and/or fax after secondary confirmation that live zebra mussels and/or their larvae have been introduced to Columbia Basin waters. The flow chart below summarizes the notification process. See the notification section of the rapid response plan for more guidance on notification roles and responsibilities.



Rapid Response Notification List

Note: the following tables are not comprehensive but provide an initial set of contacts. ***This plan assumes individuals identified in the Priority 1 table will directly make any further contacts internal to their organization (i.e., additional contracts for those organizations are not listed in tables 2 or 3).*** *After-hours contact information has been deleted from the on-line version.*

Priority 1: Notify by phone, fax, and email within 24 hours of verified report or as soon as practical						
Organization	**Name/position**	**Office Phone**	**Cell phone/ After hours**	**Fax**	**Email**	**Notes**
Portland State University, Center for Lakes and Reservoirs	**Mark Sytsma, Director/ANS Coordinator (Primary)**	**503-725-3833**	**xxxxxxxxxx**	**503-725-3834**	**sytsmam@pdx.edu**	**Will notify all other State of Oregon contacts in coordi-nation with ODFW**
Portland State University, Center for Lakes and Reservoirs	**Robyn Draheim, Assistant ANS Coordinator (Alternate)**	**503-725-4994**	**xxxxxxxxxx**	**503-725-3834**	**draheim@pdx.edu**	
Oregon Department of Fish and Wildlife	**Jim Gores, Invasive Species Coordinator (Alternate)**	**503-947-6308**	**xxxxxxxxxx**		**james.k.gores@state.or.us**	**Will coordinate with PSU for Oregon notification**
Washington Department of Fish and Wildlife	**Pam Meacham, ANS Coordinator (Primary)**	**360-902-2741**	**xxxxxxxxxx**		**meachpmm@dfw.wa.gov**	**Will notify all other State of Washing-ton contacts**
Idaho Department of Fish and Game	**Fred Partridge, ANS Coordinator (Primary)**	**208-334-3791**	**xxxxxxxxxx**		**fpartridge@idfg.idaho.gov**	**Will notify all other State of Idaho contacts**
Idaho Department of Agriculture	**Invasive Species Council Coordinator (Alternate)**		**xxxxxxxxxx**			
Montana Fish, Wildlife, and Parks	**Eileen Ryce, ANS Coordinator (Primary)**	**406-444-2448**	**xxxxxxxxxx**		**eryce@mt.gov**	**Will notify all other State of Montana contacts**
Montana Fish, Wildlife,and Parks	**Nancy Podolinsky (Alternate)**	**406-444-2449**	**xxxxxxxxxx**		**npodolinsky@mt.gov**	

Priority 1: Notify by phone, fax, and email within 24 hours of verified report or as soon as practical						
Organization	**Name/position**	**Office Phone**	**Cell phone/ After hours**	**Fax**	**Email**	**Notes**
U.S. Fish and Wildlife Service	**Paul Heimowitz, Region 1 ANS Coordinator (Primary)**	**503-872-2763**	**xxxxxxxxxx**	**503-231-2062**	**paul_heimowitz@fws.gov**	**Will notify all other USFWS contacts**
U.S. Fish and Wildlife Service	**Kevin Aitkin, ANS Coordinator, Western Washing-ton F&W Office (Alternate)**	**360-753-9508**	**xxxxxxxxxx**	**360-753-9407**	**kevin_aitkin@fws.gov**	
U.S. Geological Survey	**Scott Smith, Invasive Species Section Leader, Western Fisheries Research Center (Primary)**	**206-526-6282 X 331**	**xxxxxxxxxx**		**sssmith@usgs.gov**	**Will notify all other USGS contacts**
U.S. Geological Survey	**Tim Counihan, Western Fisheries Research Center (Alternate)**	**509-538-2299**	**xxxxxxxxxx**	**509-538-2843**	**tim_counihan@usgs.gov**	
U.S. Bureau of Reclamation	**Joe DiVittorio, Invasive Species/ IPM Manager, Office of Program & Policy Services (Primary)**	**303-445-3639**	**xxxxxxxxxx**	**702-544-0663**	**jdivittorio@do.usbr.gov**	**Will notify all other USBR contacts**
U.S. Bureau of Reclamation	**Scott Lund (Alternate)**	**208-378-5037**	**xxxxxxxxxx**		**slund@pn.usbr.gov**	
U.S. Environmental Protection Agency	**Joan Cabreza, Invasive Species Coordinator, Region 10 (Primary)**	**206-553-7369**	**xxxxxxxxxx**	**206-553-1775**	**cabreza.joan@epa.gov**	**Will notify all other EPA contacts**
U.S. Army Corps of Engineers	**Rock Peters, ANS Lead, NW Division Office (Primary)**	**503-808-4777**	**xxxxxxxxxx**	**503-808-4756**	**rock.d.peters@usace.army.mil**	**Will notify all other Corps of Engineers contacts**

Priority 1: Notify by phone, fax, and email within 24 hours of verified report or as soon as practical						
Organization	**Name/position**	**Office Phone**	**Cell phone/ After hours**	**Fax**	**Email**	**Notes**
U.S. Army Corps of Engineers	**Tim Darland, ANS Lead, Bonneville Lock and Dam (Alternate)**	**541-374-4551**	**xxxxxxxxxx**	**541-374-8761**	**Timothy.J.Darland@ nwp01.usace.army.mil**	
Bonneville Power Administration	**Jim Irish, ANS Lead, Generation Supply Department (Primary)**	**503-230-5914**	**xxxxxxxxxx**		**jtirish@bpa.gov**	**Will notify all other BPA contacts**
Bonneville Power Administration	**Heather Hergert, Crime Witness Hotline (Alternate)**	**360-418-2108**	**xxxxxxxxxx**		**hmhergert@bpa.gov**	
Pacific States Marine Fisheries Commission	**Stephen Phillips, ANS Coordinator (Primary)**	**503-595-3100**	**xxxxxxxxxx**	**503-595-3232**	**stephen_phillips@psmfc.org**	**Will notify all other PSMFC contacts**
Pacific States Marine Fisheries Commission	**Susan Anderson, ANS Admini-strative Assistant (Alternate)**	**503-595-3100**	**xxxxxxxxxx**	**503-595-3232**	**susan_anderson@psmfc.org**	
Columbia River Intertribal Fish Commission	**Blaine Parker, ANS Coordinator (Primary)**	**503-731-1268**	**xxxxxxxxxx**	**503-235-4228**	**parb@critfc.org**	**Will notify CRITFC member tribes**

Note – this list is based on information submitted following an initial solicitation for contacts. Additional Priority 1 contacts for other U.S. federal agencies (e.g., NOAA), Canadian officials, non-CRITFC tribes, local government and utility districts, and other key response organizations will be added as information becomes available.

Priority 2: Notify by fax and email within 24 hours of verified report or as soon as practical				
Name	**Affiliation**	**Fax**	**Email**	**Notes**
Anderson, Kevin	**Puget Sound Action Team**	**360-725-5456**	**kanderson@psat.wa.gov**	
Brett, Michael	**University of Washington**	**206-685-9185**	**mtbrett@u.washington.edu**	
Hargrove, Bas	**The Nature Conservancy of Idaho**	**208-343-8892**	**bhargrove@tnc.org**	
Leary, Jill	**Lower Columbia River Estuary Partnership**	**503-226-1580**	**leary@lcrep.org**	
Myers, Ralph	**Idaho Power Company**		**myers@idahopower.com**	

Note – this list is based on information submitted following an initial solicitation for contacts. Additional Priority 2 contacts for elected officials, irrigation districts, river transportation providers, ports, and others will be added as information becomes available.

Priority 3: Notify by email within 72 hours of verified report or as soon as practical			
Name	**Affiliation**	**Email**	**Notes**
Curl, Herb	**Washington Audubon Society**	**Hcurl55@comcast.net**	

Note – this list is based on information submitted following an initial solicitation for contacts. Additional Priority 3 contacts for recreational user groups, marina operators, water right holders, and others will be added as information becomes available.

Appendix D

Summary of Zebra Mussel Eradication and Control Options

Except as noted, this material is from: Messer, C. and T. Veldhuizen. 2005. Zebra Mussel Early Detection and Public Outreach Program Final Report. Report for California Bay-Delta Authority and US Dept of the Interior, Fish and Wildlife Service. CBDA Project No.99-F07, Zebra Mussel Detection and Outreach Program. 278 pp. to become available at: www.water.ca.gov/zmwatch/.

Thermal Shock

Hot water treatment can kill zebra mussels. Temperatures of 37°C and above are lethal to zebra mussels. Depending upon acclimation temperature, zebra mussels will die in about 1 hour. At winter acclimation temperatures (5 to 10°C), temperatures of 33°C and above will kill zebra mussels within 13 hours. For further information, see Table 1 in McMahon, et al.[1]

Freezing

Adult zebra mussels die when aerially exposed to freezing temperatures for varying lengths of time. Populations can be controlled by winter-time dewatering and exposing zebra mussels to freezing air temperatures. Zebra mussels die in 2 days at 0°C and at minus 1.5°C, in 5 to 7 hours at minus 3°C, and in under 2 hours at minus 10°C. Duration to mortality is less for single mussels than for clustered mussels.

Research conducted by Dr. R.F. and T.A. Ussery (in Payne[2]).

Oxygen Starvation

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[1] McMahon R.F., Ussery T.A., Miller A.C., Payne B.S. 1993. Thermal tolerance in zebra mussels (*Dreissena polymorpha*) relative to rate of temperature increase and acclimation temperature. Proceedings of the Third International Zebra Mussel Conference. EPRI TR 0102077:4-97 - 4-118, 22 pages.

[2] Payne, B.S. 1992. Freeze survival of aerially exposed zebra mussels. US Army Corps of Engineers Waterways Experiment Station Technical Note ZMR-2-09.

Oxygen is removed from the water by cycling it through oxygen-starving pumps. The developer claims the equipment can cycle 200 million gallons of water. This technology was developed by Wilson J. Browning of Amark Corp, Norfolk County, VA. Another method of removing oxygen is to add oxygen scavenging chemicals, such as sodium-meta-bisulfite and hydrogen sulfide gas (USACE-ZMIS).

Zebra mussels are able to tolerate oxygen deprivation for up to 2 weeks, provided ambient temperatures are low enough (USACE-ZMIS).

Desiccation

Instantaneous mortality occurs at 36°C. Temperatures over 32°C are lethal within 5 hours. At temperature below 30°C, time to mortality is dependent upon relative humidity.

Temperature is positively related and humidity is negatively related to adult zebra mussel mortality. As humidity increases and temperature decreases, survivorship increases (Table 1). Aerial exposure of zebra mussels during summer months, when temperatures exceed 25°C, will result in 100% mortality in 2.1 days. During winter months, 100% mortality will take longer, depending upon the relatively humidity.

Desiccation is a viable option for eradicating zebra mussels from areas that can be dewatered for several days. Alternatively, desiccation can also act as a population control method in areas that can not be completely dewatered. For example, reservoir levels can be lowered (at least 30 vertical feet) to expose zebra mussel inhabiting shallow water. The majority of the zebra mussel population inhabits shallow water within 2 to 7 m below the surface, with moderate to low densities up to 50m. Colonization is dependent upon water temperature, oxygen content, and food availability. They tend to colonize above the thermocline.

Table 1. Number of days to 100% mortality of adult zebra mussels aerially exposed to different levels of relative humidity and air temperature. Research conducted by Dr. R.F. McMahon and T.A. Ussery (in Payne[3]).

Days to 100 % Mortality at Air Temperature, °C

[3] Payne, B.S. 1992. Aerial exposure and mortality of zebra mussels. US Army Corps of Engineers Waterways Experiment Station Technical Note ZMR-2-10.

Relative Humidity, %	5	15	25
95	26.6	11.7	5.2
50	16.9	7.5	3.3
5	10.8	4.8	2.1

Benthic Mats

Researchers from the Rensselaer Polytechnic Institute in New York are investigating the use of benthic mats that would cover the sediment and zebra mussels, and smother the mussels. Research is planned to occur in Lake George, NY.

Predation

The relatively soft shells of zebra mussels and their exposure (on substrates as opposed to buried in sediment) make them vulnerable to predation. Possible predators of adult mussels are some species of carp, catfish, bullhead, sucker, sunfish, sturgeon, crayfish, and muskrats. A possible predator of veligers is the American shad. However, there is no evidence of predation control in the Great Lakes, Ohio River, and Poland. There is some evidence of population reduction in the Hudson River. Despite the lack of clear evidence of population control through predation, it is recommended that harvest of predatory species in infested waterbodies be stopped.

Chemical Treatment

[Note: The California plan from which this material originates contains a large, detailed matrix or potential effectiveness of various chemical treatment options (lethal doses, etc.). The final plan writers may want to consider including their table or a modification of that table.]

The most susceptible life stages to chemical treatment are post-spawned mussels that are in a low energy state, and veligers and pediveligers that have undeveloped shells. There are 3 general categories of chemicals used to treat zebra mussel infestations: metallic salts, oxidizing biocides, and nonoxidizing biocides. Application rates and duration data for these compounds come from laboratory studies, power plants, and water treatment plants.

Metallic salts, electrolytically dissolved metallic ions, are effective on adult mussels because of the incomplete sealing of their shells. The required exposure time for most metallic ions ranges from 5 to about 48 hours.

Oxidizing chemicals have been used by the water treatment industry for disinfection since the late 1800s and their effect on the environment is understood and documented Claudi[4]). Zebra mussels can recognize oxidizing chemicals, such as chlorine, as a toxin. Oxidizing chemicals are very irritating. They work by oxidizing the gill lamellae and other parts, eventually causing death. In response to the irritation, zebra mussels expel the offending water and close their valves for several days. Periodically, they reopen their valves to “test” the water. Depending upon water temperature, respiration rate, and stored nutrient reserves, zebra mussels can remain closed and withstand exposure for many days before reopening their valves to resume respiration and feeding. Therefore, required exposure time for oxidizing biocides is usually 1 to 3 weeks.

Zebra mussels do not detect most non-oxidizing chemicals and continue to filter water. The chemical is drawn into the mussel’s body and attacks the cell walls. The cells lose the ability to maintain their chemical balance, and the mussel dies. Because the mussels continue to filter, exposing themselves to the chemical, treatment with non-oxidizing chemicals can be accomplished in hours as opposed to weeks.

The most commonly used non-oxidizing compounds are proprietary molluscicides (e.g. Clamtrol, Bulab, Bayluscide). They are applied at high concentrations, and, in most cases, the water must be detoxified after treatment. These compounds are usually deactivated by releasing slurry of bentonite clay into the water. The cationic or surfactant active ingredients bind onto the clay, becoming inactive. The clay settles out of the water column and becomes part of the bed sediments. The compound is microbially degraded into nontoxic products. These chemicals are less effective at lower water temperatures, so treatment is recommended during warmer months. The chemicals are usually administered with equipment supplied by the vendors.

Non-oxidizing chemicals were used to control the Asian clam in the southeastern US (Green[5]).

Additional information on most of these chemicals, such as formula, manufacturer, and application method, is available at http://www.wes.army.mil/el/zebra/zmis/idxlist.htm.

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[4] Claudi, R. and G. Mackie. 1994. Zebra mussel monitoring and control. Lewis Publishers, Inc. Boca Raton, FL.`
[5] Green, R.F. 1995. Strategies for application of non-oxidizing biocides. Proceedings of the Fifth International Zebra Mussel and Other Aquatic Nuisance Organisms Conference, Toronto, CA, February 1995: 175-181.

Bacterial Toxin

Experimental research is occurring on a toxin produced by *Pseudomonias fluorescens*, a soil bacterium. The toxin destroys the digestive gland of zebra mussels, but reportedly does not harm fish or native mussels. Currently, it is not economically feasible to produce large amounts of this biotoxin.

No-Growth Materials (anti-fouling paints) – To prevent zebra mussel attachment.

Appendix E

Matrix of eradication and control options for various zebra mussel waterbody infestation scenarios.
(From: Messer, C. and T. Veldhuizen. 2005)

Eradication and control options for various zebra mussel waterbody infestation scenarios.		
Population Level / Waterbody	**Isolated Population**	**Widespread Population**
Pond, Isolated, non-draining	• Evaluate for natural control (e.g. Winter freeze, summer desiccation) • Chemically treat area and buffer zone • Quarantine and/or stop all recreational and commercial uses in infested area and buffer zone • Mandatory cleaning of departing vessels and equipment	• Chemically treat entire waterbody • Stop water diversions, if any, and chemically treat diversion infrastructure • Mandatory cleaning of all departing vessels and equipment • Quarantine and/or stop all recreational uses
Pond, draining	• Chemically treat released water or prevent water release • Chemically treat area and buffer zone • Monitor for spread within pond and downstream • Quarantine and/or stop all recreational and commercial uses in infested area and buffer zone • Mandatory cleaning of departing vessels and equipment	• Minimize or prevent water release • Chemically treat released water • Chemically treat diversion infrastructure, if any • Monitor for spread downstream • Chemically treat entire waterbody • Mandatory cleaning of all departing vessels and equipment • Quarantine and/or stop all recreational and commercial uses

Eradication and control options for various zebra mussel waterbody infestation scenarios.		
Population Level / **terbody**	**Isolated Population**	**Widespread Population**
Small Reservoir	• Minimize water releases • Chemically treat released water • Chemically treat area and buffer zone • Monitor for spread within reservoir and downstream • Quarantine and/or stop all recreational and commercial uses in infested area and buffer zone • Mandatory cleaning of departing vessels and equipment	• Evaluate need to reduce reservoir volume through water releases • Chemically treat released water • Chemically treat diversion infrastructure, if any • Monitor for spread downstream • Chemically treat entire waterbody • Mandatory cleaning of all departing vessels and equipment • Quarantine and/or stop all recreational and commercial uses
Large Reservoir	• Reduce reservoir volume • Chemically treat released water • Chemically treat infested area and buffer zone • Monitor for spread within reservoir and downstream • Quarantine and/or stop all recreational and commercial uses in infested area and buffer zone • Mandatory cleaning of departing vessels and equipment	• Chemically treat released water • Monitor for spread downstream • Chemically treat diversion infrastructure, if any • Evaluate potential for a water level drawdown to reduce the population • Evaluate ability to chemically treat entire waterbody • Prevent spread to upstream waterbodies and other watersheds • Quarantine and/or stop all recreational and commercial uses • Mandatory cleaning of all departing vessels and equipment

Eradication and control options for various zebra mussel waterbody infestation scenarios.		
Population Level / **terbody**	**Isolated Population**	**Widespread Population**
River, Small Volume	• Minimize or stop inflow and increase upstream water diversions to reduce stream volume and flow rate • Install veliger settlement materials at downstream end of population • Create pool conditions at downstream end of population to facilitate veliger settlement (e.g., installation of temporary weir) • Treat with molluscicide • Detoxify downstream of infested area • Monitor for spread downstream • Prevent spread to upstream waterbodies and other watersheds • Quarantine and/or stop all recreational and commercial uses in infested area and buffer zone • Installation of travel barrier and mandatory cleaning station for all vessels traveling upstream via waterway • Mandatory cleaning of all departing vessels and equipment	• Minimize or stop inflow and increase upstream water diversions to reduce stream volume and flow rate • Treat with molluscicide • Detoxify downstream of infested area • Monitor for spread downstream • Prevent spread to upstream waterbodies and other watersheds • Quarantine and/or stop all recreational and commercial uses • Installation of travel barrier and mandatory cleaning station for all vessels traveling upstream via waterway • Mandatory cleaning of all departing vessels and equipment

Eradication and control options for various zebra mussel waterbody infestation scenarios.		
Population Level / terbody	Isolated Population	Widespread Population
River, Large Volume	• Minimize inflow and increase upstream water diversions to reduce stream volume and flow rate • Install veliger settlement materials at downstream end of population • Create pool conditions at downstream end of population to facilitate veliger settlement (e.g., installation of temporary weir) • Treat with molluscicide • Detoxify downstream of infested area • Monitor for spread downstream • Prevent spread to upstream waterbodies and other watersheds • Quarantine and/or stop all recreational and commercial uses in infested area and buffer zone • Installation of travel barrier and mandatory cleaning station for all vessels traveling upstream via waterway • Mandatory cleaning of all departing vessels and equipment	• Prevent spread to upstream waterbodies and other watersheds • Quarantine and/or stop all recreational and commercial uses • Mandatory cleaning of all departing vessels and equipment • Installation of travel barrier and mandatory cleaning station for all vessels traveling upstream via waterway • Closure of unattended boat ramps, especially In zebra mussel-free areas • Mandatory inspection/cleaning of all vessels entering zebra mussel-free waterbodies • Evaluate ability to chemically treat

Eradication and control options for various zebra mussel waterbody infestation scenarios.		
Population Level / **terbody**	**Isolated Population**	**Widespread Population**
Estuary	• Install veliger settlement materials at perimeter of population • Divert upstream water to reduce river volume and flow rate (e.g. Rock barrier) • Create pool conditions at downstream end of population to facilitate veliger settlement (e.g., installation of temporary weir, tidal flow/rock barrier) • Treat with molluscicide • Detoxify downstream of infested area • Monitor for spread • Prevent spread to upstream waterbodies and other watersheds • Quarantine and/or stop all recreational and commercial uses in infested area and buffer zone • Installation of travel barrier and mandatory cleaning station for all vessels traveling upstream via waterway • Mandatory cleaning of all departing vessels and equipment	• Eradication doubtful • Implement population level control measures (e.g. Salt water intrusion during spawning season and veliger settlement) • Prevent spread to upstream waterbodies, other watersheds, pumping plants, and aqueducts/diversion canals • Mandatory cleaning of all departing vessels and equipment • Closure of unattended boat ramps, especially in zebra mussel-free areas • Installation of travel barrier and mandatory cleaning station for all vessels traveling upstream via waterway • Mandatory inspection/cleaning of all vessels entering zebra mussel-free waterbodies • Establish regulations for ships traveling to/from ports of the Columbia River • Evaluate treatment/spread prevention at all points of diversion

Eradication and control options for various zebra mussel waterbody infestation scenarios.		
Population Level / Waterbody	**Isolated Population**	**Widespread Population**
Water Diversions	• If only one facility is impacted, transfer all diversions to alternate facility(ies) • Drain and desiccate facilities, chemically treat standing water - OR - • Isolate infested area and buffer zone with temporary barriers, chemically treat • Chemically treat removed water or quarantine and discharge the mussel-infected water to safe disposal area • Monitor for downstream spread • Mandatory cleaning of all vessels and equipment • Quarantine and/or stop all recreational and commercial uses of aqueduct • Retrofit facility(ies) to minimize impacts	• If only one diversion system is impacted, transfer all diversions to other facility(ies); • Drain and desiccate facilities, chemically treat standing water • If both facilities/water transfer infrastructure are impacted: o Chemically treat water before transferring to “downstream” uses o Chemically treat water before entrance into the facilities) o Mandatory cleaning of all vessels and equipment departing facility(ies) o Quarantine and/or stop all recreational and commercial uses of contaminated facilities o Desiccate and chemically treat one facility and aqueduct at a time; continue diversions through alternate facility(ies) • Retrofit facility(ies) to minimize impacts

Appendix F

Methods for In-Situ Evaluation of the Chemical Control Effectiveness

(Messer, C. and T. Veldhuizen. 2005)

Mortality Monitoring

- Suspend test cages containing attached live mussels into the water to be treated.
- Use at least 10 mussels per cage and multiple cages per waterbody or use a statistically designed replication study.
- Monitor kill rate as chemical is administered.
- Conduct multiple tests for alternative chemical concentrations based on kill success of mussels in test cages.
- Follow by extensive inspections of the facility(ies) (surface and by diver) looking for live mussels.

Visual determinations of dead mussels

- Valve gaping with no response of exposed mantle tissue to external stimuli.
- For mussels with gaping shells failure of plantigrade mussel to respond to the touch of a probe.
- If shell is closed absence of ciliary beating and adductor muscle activity when inserting probe between the valves of the mussel.

Mortality verification

- Monitor test cages conducting mortality counts every 24 hours post-treatment or in accord with the chosen statistical design.
- Transfer test cages to recovery tank(s) to test for false-positive kill observations.
- Transfer in-situ-killed mussels to recovery tank(s) for false-positive kill observations