Pest Risk Assessment for
Zebra and Quagga Mussels in Oregon

IDENTITY

Zebra and quagga mussels are closely related filter-feeding freshwater mussels in the genus *Dreissena* that produce planktonic larvae that are free-swimming in the water column. Larvae eventually settle to the bottom and grow into adults that attach to hard surfaces using byssal threads. Because of their similarities we will refer to both zebra and quagga mussels as dreissenid mussels throughout this risk assessment.

Zebra Mussels: Dreissena polymorpha
Taxonomic *Rank*: Bivalvia: Veneroida: Dreissenidae

Quagga mussel: Dreissena rostriformis bugensis
Taxonomic Rank: Bivalvia: Veneroida: Dreissenidae

Photo courtesy of USGS Nonindigenous Aquatic Species

RISK RATING SUMMARY

Relative Risk Rating: Very High
Numerical Score: **9 (on a 1-9 scale)**
Uncertainty: Low to Moderate

This risk evaluation is a summary of information compiled by the Center for Lakes and Reservoirs at Portland State University and the U.S. Geological Survey (Wells et al. 2008; Wells et al. 2009), and other risk evaluations (Cohen and Weinstein 1998; Drake and Bossenbroek 2004; Ramcharan et al. 1992; Ramcharan et al. 1997; Whittier et al. 2008).

Based on a high risk of establishment, spread, and economic and ecological harm, we conclude that the risk posed to Oregon by dreissenid mussels is very high. Preventing the introduction and establishment of dreissenid mussels should remain a high priority for the Pacific Northwest (PNW), Columbia River Basin (CRB), and the state of Oregon. It is advisable that monitoring programs be established at the sites found to be at highest risk by Wells et al. (2009; see further discussion under Establishment Potential below). Public education, especially with recreational boaters, is another necessary tool in efforts to reduce the likelihood of dreissenid mussel establishment and spread in the CRB.

RULES AND REGULATIONS

Dreissenid mussels are subject to regulation by both the federal and state governments. It is prohibited by the Federal Lacy Act to import, transport, or acquire live zebra mussels (50 CFR 16.13). The National Invasive Species Act of 1996 (NISA) (P.L. 101-636), an amendment to the 1990 Act, established the National Aquatic Nuisance Species Task Force to coordinate government efforts relating to species such as dreissenid mussels with those of the private sector. The National Task Force created regional panels such as the Western Regional Panel (WRP) to limit the introduction, spread and impacts of aquatic nuisance species in the West. The WRP is a panel of public and private entities that summarizes current strategies to address the invasion of dreissenid mussels in the

West, and identifies and prioritizes specific actions needed to prevent the spread and mitigate impacts. The WRP and the National Task Force also created the 100th Meridian Initiative, which is a cooperative effort between local, state, provincial, regional and federal agencies to pool the resources of the various stakeholders to increase coordination and the efficacy of their efforts to prevent the westward spread of dreissenid mussels and other aquatic nuisance species in North America. In Oregon, the Oregon Department of Environmental Quality regulates ballast water, which was the probable likely vector for the original introduction of zebra and quagga mussels into North America, in order to protect the waters of the Oregon from aquatic nuisance species (OAR 340-143). It is illegal to import, possess, confine, transport, or sell dreissenid mussels (OAR 635-056-0050) and it is illegal to launch a boat into waters of the state that is contaminated by aquatic invasive species (ORS 830.990).

OVERVIEW

Dreissenid mussels are bivalve filter feeders that can cause extensive changes in the ecosystems in which they become established. They attach to hard substrates, and through their filter feeding remove particles from the water column, clarifying the water and transferring biomass from pelagic to benthic portions of the water column (Sousa et. al. 2009).

Dreissenid mussels are native to the watersheds of the Aral, Azov, Black, and Caspian seas of eastern Europe and western Asia. It is likely that dreissenid mussels were introduced to the Great Lakes of North America in the ballast water of cargo ships in the mid 1980s (Leung et al. 2004). Dreissenid mussels spread quickly and were established in 20 states and two Canadian providences by 1996. Canals and interconnected water bodies allowed rapid downstream dissemination of floating planktonic larvae, and adults were inadvertently spread with barge and trailered boat traffic (Lucy et al. 2004; Johnson et al. 2001; Karatayev et al. 2007). By 2004 dreissenid mussels had spread throughout the Mississippi drainage as far west as the Oklahoma River and as far south as New Orleans and occupy the water bodies in much of the central and eastern United States (Aldridge 2004).

The westward expansion of dreissenid mussels from the Great Lakes and Mississippi watershed was slower than their spread in the central and eastern portions of the US. Westward expansion at this point, was primarily through overland dispersal events to isolated lakes and reservoirs and not through interconnected water bodies (Bossenbroek 2007). Rapid downstream expansion, however, occurred in western waters once mussels were established. Mussels were found established in Lake Mead, NV in 2007, and by 2008, dreissenid mussels had spread throughout the Arizona Central Canal and the Colorado River Aqueduct system from Lake Havasu to Riverside California, and in the lakes and reservoirs surrounding San Diego, and Lake Pleasant, AZ (USGS 2009).

On January 16th 2008, the California Department of Fish and Game announced that dreissenid mussels had been found in San Justo Reservoir just east of Gilroy, California. This reservoir is approximately 1,000 miles from the nearest known zebra mussel-infested water body and only five hours from the Oregon border on a trailered boat. In 2008, zebra and quagga mussel larvae were detected in Electric Lake, UT and Red Fleet Reservoir, UT, respectively (USGS 2009), only 100 miles from the headwater of the Snake River where downstream movement could be rapid. There have been multiple discoveries of overland transportation of dreissenid mussels on trailered boats located in Oregon, Washington, California and Montana (USGS 2009).

RISK RATING DETAILS

Establishment Potential is High

Justification:

Now that there are established populations west of the Rocky Mountains, the likelihood of viable mussels reaching PNW water bodies is increased. As in all invasions, propagule pressure is important, but the limnological properties of receiving water can constrain the successful establishment of dreissenid mussels. The salinity, dissolved calcium concentration, pH, and temperature range are important limiting factors in dreissenid mussel establishment (Hincks and Mackie 1997; Ram et al. 1996; Nichols 1996; McMahon 1996).

Some water bodies in Oregon provide a more suitable habitat for the mussels than others. Calcium is physiologically important to dreissenid mussels, and they do not seem to establish in areas where the concentrations of dissolved calcium are below 12 mg/L (Hincks and Mackie 1997; Nichols 1996). Wells et al. (2009) used Ca^{2+}, pH, and boater recreational data to prioritize water bodies in the PNW in terms of their likelihood for dreissenid mussel establishment and introduction. They determined that many water bodies in eastern and central Oregon were at high to medium risk for dreissenid mussel establishment and introduction (e.g. Snake, Columbia, and John Day Rivers, East Lake, Paulina Lake, Prineville Reservoir, and Owyhee Reservoir). They also reported that although most water bodies in western Oregon were low risk for dreissenid establishment, many of these water bodies were high risk for mussel introduction based on the amount of recreational boating they receive (e.g. Willamette River, Lake Billy Chinook, Deschutes River, Fern Ridge Reservoir, Dexter Reservoir, Foster Reservoir, Detroit Lake, and Diamond Lake).

There is uncertainty, however, associated with evaluating establishment potential based on particular environmental parameters and assigned thresholds. For example, different parameters have been used in risk evaluations, and mussel larvae have recently been detected in water bodies previously considered to have a low risk of establishment potential (e.g. Grand Lake, CO with less than 12 mg Ca^{2+}/ L) (USGS 2009). Furthermore, other nonindigenous bivalves, such as *Corbicula fluminea*, which is widespread and abundant in Oregon can increase sediment interstitial water calcium concentration (Whitman et al. 2008), which may facilitate dreissenid mussel establishment.

Spread Potential is High

Justification:

Dreissenid mussels can reach new water bodies through natural or human-aided transport. Natural dispersal occurs through drifting larvae, or by adults attached to floating objects. Human-aided transport can be through ballast water, or by attachment to hulls of trailered boats and barges, and in bait and nursery stock (Johnson et al. 2001; Karatayev et al. 2007). Overland transportation by recreational boaters is the most likely pathway for the transportation of nonindigenous aquatic species from established populations in invaded lakes and rivers to inland water bodies (Johnson et al. 2001; Timar and Phaneuf 2009). Adult mussels may survive out of water up to five days in dry environments and for several weeks in wet fishing gear (Timar and Phaneuf 2009). Leung et al. (2004) reported that the chance of establishment of aquatic invasive species by overland transport goes up by a factor of the square of the distance from existing populations. The risk of invasion to Oregon has dramatically increased with the populations now established in California within five driving hours of the border as well as other western states including Colorado and Utah.

The state of Oregon has determined that it is critical to prevent the introduction of dreissenid mussels into water bodies hydraulically connected to Oregon waters. In 2009, the Oregon State Marine Board established Oregon's new Aquatic Invasive Species Program which goes into effect in 2010. This program is designed to reduce the spread of dreissenid mussels through boat inspections and public education. Ballast water discharges in Oregon waters are regulated through OAR 340-143.

Environmental Impact Potential is High

Justification:

Once established, dreissenid mussels can dramatically alter the ecology of a water body. Their filtering action enhances water clarity and changes the food web by shifting production from the pelagic to the benthic portions of the water column. By attaching themselves to the surfaces of other bivalves, dreissenid mussels can starve other freshwater mussels and drive indigenous populations to local extinction. Dreissenid mussels can affect dissolved oxygen through respiration, and dissolved calcium carbonate concentrations through shell building (Strayer 2009).

Economic Impact Potential is High

Justification:

Dreissenid mussels can cause substantial economic damage by infesting the components of municipal, industrial, and agricultural water systems. The mussels attach themselves to the hard substrates of pipes, dams, and diversion pathways restricting the flow of water through the system impacting component service life, system performance, and maintenance activities.

The yearly cost to power plants and municipal drinking water systems in North America has been estimated at between $267 million and $1 billion dollars (Connelly et al. 2007; Pimentel 2005). Establishment of dreissenid mussels in the CRB would be expensive, requiring extensive maintenance to the nuclear power plant and the hydroelectric dams, fish ladders and irrigation pumping. In an economic impact report prepared for Bonneville Power the onetime cost to install mussel treatment systems was estimated at more than $23 million dollars. The yearly costs were estimated at $1.5 million (Phillips et al. 2005).

Human Health Impact Potential is Low

Justification:

Dreissenid mussels pose a low risk to human health. Dead and decaying mussels wash ashore, and the sharp shells can injure feet of humans and pets. Filter-feeding dreissenid mussels accumulate toxins and ingestion could expose humans to elevated levels of heavy metals and other toxins. There are no reports, however, of humans consuming dreissenids mussels.

References

Aldridge, D.C., 2004. The recent and rapid spread of the zebra mussel (*Dreissena polymorpha*) in Great Britain. *Biological Conservation*. **119**: 253-261.

Bossenbroek, J. M., 2007. Forecasting the Expansion of Zebra Mussels in the United States. *Conservation Biology*. **21**(3): 800–810.

Cohen, A.N. and A. Weinstein, 1998. The Potential Distribution and Abundance of Zebra Mussels in California. San Francisco Institute.

Connelly N., C.R. O'Neill, B.A. Knuth, and T.L. Brown, 2007. Economic Impacts of Zebra Mussels on Drinking Water Treatment and Electric Power Generation Facilities. *Environmental Management*. **40**(1): 105–112.

Drake, J.M., and J.M. Bossenbroek, 2004. The Potential Distribution of Zebra Mussels in the United States. *BioScience*. **54**(10): 931-941.

Hincks, S.S. and G.L. Mackie, 1997. Effects of pH, calcium, alkalinity, hardness, and chlorophyll on the survival, growth, and reproductive success of zebra mussel (*Dreissena polymorpha*) in Ontario lakes. *Can. J. Fish. Aquat. Sci.* 54:2049-2057.
Johnson L.E, A. Ricciardi, J.T. Carlton, 2001. Overland dispersal of aquatic invasive species: a risk assessment of transient recreational boating. *Ecological Applications*. 11(6): 1789-1799.
Karatayev, A. Y., D.K. Padilla, D. Minchin, D. Boltovskoy, L.E. Burlakova, 2007. Changes in global economies and trade: the potential spread of exotic freshwater bivalves. *Biological Invasions*. 9:161-180.
Leung, B., J.M. Bossenbroek, and D.M. Lodge, 2004. Boats, Pathways, and Aquatic Biological Invasions: Estimating Dispersal Potential with Gravity Models. *Biological Invasions*. **8**(2): 241–254.
Lucy, A., J. Buchan, and D.K. Padilla, 1999. Estimating the Probability of Long-Distance Overland Dispersal of Invading Aquatic Species. *Ecological Appplications*. **9**(1):254-265.
McMahon, R.F., 1996. The Physiological Ecology of the Zebra Mussel, *Dreissena polymorpha*, in North America and Europe. *Amer. Zool*. 36:339-363.
Nichols, S. J., 1996. Variations in the Reproductive Cycle of *Dreissena polymorpha* in Europe, Russia, and North America. *Amer. Zool*. 36:311-325.
Phillips, S., T. Darland, and M. Sytsma. 2005. Potential Economic Impacts of Zebra Mussels on Hydropower Failities in the Columbia River Basin. Prepared for Bonneville Power Administration. 22 pg.
Pimentel, D., 2005. Aquatic Nuisance Species in the New York State Canal and Hudson River Systems and the Great Lakes Basin: An Economic and Environmental Assessment. *Environmental Management* **35**(5):692–701.
Ram, J., P.P. Fong, and D.W. Garton, 1996. Physiological Aspects of Zebra Mussel Reproduction: Maturation, Spawning, and Fertilization. *American Zoologist*. **36**(3):326-338. (1996)
Ramcharan, C.W., D.K. Padilla, and S.I. Dodson, 1992. A multivariate model for predicting population fluctuations of *Dreissena polymorpha* in North American lakes. *Can. J. Fish. Aquat. Sci*. **49**: 150-158.
Ramcharan, C.W., D.K. Padilla, and S.I. Dodson, 1997. Models to Predict Potential Occurrence and Density of the Zebra Mussel, *Dreissena polymorpha*. *Can. J. Fish. Aquat Sci*. **49**:2611-2620.
Sousa, R., J.L. Gutiérrez, and D.C. Aldridge, 2009. Non-indigenous invasive bivalves as ecosystem engineers. *Biological Invasions*.**11**(10):2367–2385.
Strayer, D.L., 2009. Twenty years of zebra mussels: lessons from the mollusk that made headlines. *Front Ecol Environ*. **7**(3): 135–141.
Timar, L., and D.J. Phaneuf, 2009. Modeling the human-induced spread of an aquatic invasive: The case of the zebra mussel. *Ecological Economics*. **68**(12):3060–3071.
U.S. Geological Survey, 2009. Nonindigenous Aquatic Nuisance Species (NAS) data available on the World Wide Web, accessed 2010 at URL: http://nas.er.usgs.gov.
Wells, S., M. Sytsma, and R. Draheim, 2008. Prioritizing zebra and quagga mussel monitoring in Columbia River Basin. Unpublished.
Wells, S., T.D. Counihan, A. Puls, M. Sytsma, and B. Adair. 2009. Prioritizing zebra and quagga mussel monitoring in the Columbia River Basin. Prepared for Bonneville Power Administration. 82 pg.
Whitman, M., J. Rueter, G. Schladow, S Hackley, B. Allen, Chandra, S. and A. Caires. 2008. Asian clam (Corbicula fluminea) of Lake Tahoe: Preliminary scientific findings in support of a management plan. Tahoe Environmental Research Center and University of Nevada, Reno.
Whittier, T.R., P.L. Ringold, A.T. Herlihy, and S.M. Pierson, 2008. A calcium-

based invasion risk assessment for zebra and quagga mussels (*Dreissena* spp). Front. Ecol. Environ. 6, doi 10.1890/070073.

FORMAT
This pest risk assessment (PRA) is based on the format used by the Exotic Forest Pest Information System for North America. For a description of the evaluation process used, see Step 3- Pest Risk Assessment under Guidelines at:
http://spfnic.fs.fed.us/exfor/download.cfm

AUTHORS
DeWitt Montgomery, Graduate Student, Department of Biology, Portland State University
Steve Wells, Research Assistant, Environmental Sciences & Management, Portland State University

DATE: April 15, 2010