Zebra Mussel (*Dreissena polymorpha*)
Ecological Risk Screening Summary

U.S. Fish and Wildlife Service, February 2011
Revised July 2015


Photo (edited): Amy Benson – USGS

1 Native Range, and Status in the United States

Native Range
From Birnbaum (2011):

"Native to the drainage basins of the Black, Caspian and Aral Seas (Gollasch and Leppäkoski 1999). *D. polymorpha* has been found as fossil in Central and Western Europe (Dr. Stefan Nehring, pers. comm.)"

Status in the United States
From Benson et al. (2015):

"By 1990, zebra mussels had been found in all the Great Lakes. The following year, zebra mussels escaped the Great Lakes basin and found their way into the Illinois and Hudson rivers. The Illinois River was the key to their introduction into the Mississippi River drainage which covers over 1.2 million square miles. By 1992, the following rivers had established populations of zebra mussels: Arkansas, Cumberland, Hudson, Illinois, Mississippi, Ohio, and Tennessee. By 1994, the following states had reported records of zebra mussels within their borders or in water bodies adjacent to their borders: **Alabama, Arkansas, Illinois, Indiana, Iowa, Kentucky,**

Louisiana, Michigan, Minnesota, Mississippi, Missouri, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Utah, Vermont, West Virginia, and **Wisconsin** (Benson 2012). More recently, **Connecticut** has been added to the list of states where zebra mussels have been found. In 2002, zebra mussels were found in a small isolated quarry in Virginia, a first for this state. During the summer of 2003, zebra mussel larvae known as veligers were collected in the Missouri River, the stretch of the river shared by both **Nebraska** and **South Dakota**. In January 2008, zebra mussels were discovered in San Justo Reservoir in central **California** (D. Norton, pers. comm.), in Pueblo Reservoir in Pueblo (V. Milano, pers. comm.) and Grand Lake, 50 miles northwest of Denver, **Colorado** (E. Brown, pers. comm.). A population in Lake Texoma on the border of **Texas** and Oklahoma was confirmed in June 2009 (B. Hysmith, pers. comm.). A lake in western **Massachusetts** became infested in July, 2009 (T. Flannery, pers. comm.). Most recently, June 2010, a single veliger was detected in a plankton sample from the Red River at Wahpeton, **North Dakota** (NDGFD 2010)."

Means of Introductions to the United States

From Benson et al. (2015):

"A release of larval mussels during the ballast exchange of a single commercial cargo ship traveling from the north shore of the Black Sea to the Great Lakes has been deduced as the likely vector of introduction to North America (McMahon 1996). Its rapid dispersal throughout the Great Lakes and major river systems was due to the passive drifting of the larval stage (the free-floating or "pelagic" veliger), and its ability to attach to boats navigating these lakes and rivers (see Remarks, below). Its rapid range expansion into connected waterways was probably due to barge traffic where it is theorized that attached mussels were scraped or fell off during routine navigation. Overland dispersal is also a possibility for aiding zebra mussel range expansion. Many small inland lakes near the Great Lakes unconnected by waterways but accessed by individuals trailering their boats from infested waters, have populations of zebra mussels living in them. At least nineteen trailered boats crossing into California had zebra mussels attached to their hulls or in motor compartments; all were found during inspections at agricultural inspection stations. Under cool, humid conditions, zebra mussels can stay alive for several days out of water."

Remarks

N/A

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2015):

"Kingdom Animalia
  Subkingdom Bilateria
    Infrakingdom Protostomia
      Superphylum Lophozoa
        Phylum Mollusca
          Class Bivalvia

Subclass Heterodonta
Order Veneroida
Superfamily Dreissenoidea
Family Dreissenidae
Genus Dreissena
Species *Dreissena polymorpha* (Pallas, 1771) – zebra mussel"

"Taxonomic Status: valid."

Size, Weight, Age

From Birnbaum (2011):

"The shell is triangular (height makes 40-60 % of length) or triagonal with a sharply pointed shell hinge end (umbo). The maximum size of *D. polymorpha* can be 5 cm, though individuals rarely exceed 4 cm (Mackie *et al*. 1989)."

"Larvae are planktonic for 2-4 weeks, can mature within the first year of life under optimal conditions; maturity in the second year is more usual."

From Benson et al. (2015):

"The life span is variable, but can range from 3–9 years."

Environment

From Birnbaum (2011):

"Estuarine habitats, lakes, urban areas, water courses"

From Benson et al. (2015):

"Have been found to tolerate a range of salinities, from 0.6 ‰ (Rhine River) to 10.2 ‰ (Caspian Sea) with N.A. populations generally tolerating salinity up to 4 ‰."

Climate/Range

From Murphy (2008):

"Temperate."

Distribution Outside the United States

From DAISIE (2006):

"Introduced to north-west Russia, central and western Europe, Scandinavia, Britain, Ireland and North America.; in the 1920's it appeared in Sweden, in the 1960's it was found in alpine lakes around the Alps and reached Italy in 1977, Ireland by 1994 and Spain by 2001."

Means of Introduction Outside the United States

From Birnbaum (2011):

"Ship ballast water*:* The main pathways of the expansion in the range of *D. polymorpha* are through oceanic shipping, in ballast water, and inland navigation, through solid ballast and other cargoes.
Floating vegetation/debris*:* ...attach to floating material and may readily be transported on vegetation or flotsam.
Pet/aquarium trade*:* ....possibly introduced into the wild by aquarium dumping."

Short description

From DAISIE (2006):

"*Dreissena polymorpha* is a member, of a small superfamily of bivalve molluscs whose three component genera are restricted to estuarine and freshwater habitats (Morton [1969]), forming dense colonies on various hard substrates in fresh and slightly brackish waters. It has brownish-yellowish triangular shells (up to 50 mm) with dark and light colored ("zebra") zigzag banding. It is a filter feeder of microscopic plankton organisms and organic particles."

Biology

Development:

From Murphy (2008):

"There are three stages in the life of a zebra mussel. The speed of development depends on temperature -- warmer mussels grow faster. About 3-5 days after fertilization, a tiny larva that emerges from the egg. This stage is called the veliger."

From Benson et al. (2015):

"Oogenesis occurs in autumn, with eggs developing until release and fertilization in spring. In thermally polluted areas, reproduction can occur continually through the year."

"Sexually mature at 8–9 mm in shell length (i.e. within one year)."

"Filter feed on a wide range of size particles, but select only algae and zooplankton between 15 and 400 microns. Larval stages of the mussel feed on bacteria."

Lifespan/Longevity:

From McMahon (1996):

"High growth rates and short life spans allow *D. polymorpha* to rapidly reach high densities in favorable habitats (Claudi and Mackie, 1993)."

"Are highly starvation tolerant."

Human uses

From Birnbaum (2011):

"Due to its sensitivity to anthropogenic influences *Dreissena* is important as a bioindicator and biomonitoring organism (Franz 1992, in Birnbaum 2006), and quantitative assessments have been conducted regularly since the 1960s in the context of water quality surveys (e.g. in the Rhine) (Schiller 1990, in Birnbaum 2006)."

"Crushed shells of the zebra mussel can be used as fertilizer and poultry feed (Birnbaum 2006)."

"Zebra mussels have been used as fishing bait and for fish meal production (DAISIE 2006)."

Diseases

There are no known OIE-reportable diseases for this species.

Threats to humans

From DAISIE (2006):

"Multiple economic impacts, including: fisheries (interference with fishing gear, prey for commercial fish, alteration of fish communities), aquaculture (fouling of cages); water abstractions (clogging of water intake pipes); aquatic transport (fouling of ship hulls and navigational constructions). Invasion of the zebra mussels to the North America is causing annual multimillion losses to the economy."

3 Impacts of Introductions

Biodiversity Impact

From Benson (2015):

"*Dreissena* caused diatom abundance declines of 82–91% and transparency as measured by Secchi depth increased by 100% during the first years of the invasion in Lake Erie (Holland 1993). As the invasion spread eastward during 1988 to 1990, successive sampling stations recorded declines in total algae abundance from 90% at the most western station to 62% at the most eastern (Nichols and Hopkins 1993)."

"Biomagnification of Polychlorinated Biphenyls (PCBs) was observed in *Gammarus* associated with zebra mussels, indicating concentration of pollutants in zebra mussel feces or pseudofeces can transfer to other trophic levels (Bruner et al. 1994)."

"The zooplankton abundance dropped 55-71% following mussel invasion in Lake Erie, with microzooplankton more heavily impacted (MacIsaac et al. 1995). Mean summer biomass of zooplankton decreased from 130 to 78 mg dry wt. m-3 between 1991 and 1992 in the inner portion of Saginaw Bay. The total biomass of zooplankton in the Hudson River declined 70% following mussel invasion, due both to a reduction in large zooplankton body size and reduction in microzooplankton abundance. Reductions in zooplankton biomass may cause increased competition, decreased survival and decreased biomass of planktivorous fish. Alternatively, because microzooplankton are more heavily impacted by zebra mussels, the larval fish population may be more greatly affected than later life stages. This may be especially important to inland lakes with populations of pelagic larval fish such as bluegills. Benthic feeding fish may benefit as opposed to planktivorous fish, or behavioral shifts from pelagic to benthic-feeding may occur. In addition, proliferation of macrophytes may alter fish habitat. Experimental evidence exists that zebra mussels can reduce the growth rate of larval fish through food web interactions (Raikow 2004)."

"Other effects include the extirpation of native unionid clams through epizootic colonization (Schloesser et al. 1996, Baker and Hornbach 1997). Zebra mussels restrict valve operation, cause shell deformity, smother siphons, compete for food, impair movement and deposit metabolic waste onto unionid clams. Survival rates of native unionid mussels in the Mississippi River, Minnesota have been shown to decline significantly with the increase in zebra mussel colonization (Hart et al. 2001).To date, unionids have been extirpated from Lake St. Clair and nearly so in western Lake Erie."

"Some effects have been hypothesized as worst-case scenarios. For example, zebra mussels may cause a shift from pelagically to benthically-based food webs in inland lakes. Zebra mussels may also shift lakes from a turbid and phytoplankton-dominated state to clear and macrophyte-dominated state, i.e. between alternative stable equilibria (Scheffer et al. 1993)."

From Ricciardi et al. (1998):

"A comparison of species loss at various sites before and after invasion indicates that *D. polymorpha* has accelerated regional extinction rates of North American freshwater mussels by 10-fold. If this trend persists, the regional extinction rate for Mississippi basin species will be 12% per decade. Over 60 endemic mussels in the Mississippi River basin are threatened with global extinction by the combined impacts of the *D. polymorpha* invasion and environmental degradation."

From DAISIE (2006):

"It competes for space and food with native mussels and other filter-feeding organisms and bioaccumulates pollutants. Its high consumption of phytoplankton results in increased water clarity. It is a food source for birds and benthophagous demersal fish. It causes severe habitat alterations."

From Ciborowski (2007):

"Before the arrival of zebra mussels, there were approximately 40 species of native mussels in the Detroit River and approximately 20 in Lake St. Clair. Nalepa et al. (1996) collected *Unionidae* from 29 sites in Lake St. Clair in 1986 (before the first zebra mussels were found), in the years 1990, 1992, and 1994. They collected 281 (18 species), 248 (17 species), 99 (12 species), and 6 (5 species) native mussels in the four years, respectively, which shows the devastating impact to native mussels."

“The solid waste particles (feces and pseudofeces) from zebra mussels are much larger than the food particles eaten, and build up on the lake bottom, thereby transferring energy from the pelagic (open water) to the benthic (bottom) zone. Pseudofeces are materials that collect on the zebra mussel’s gills and are rejected before entering the gut. Through filtration, zebra mussels clarify the water and decrease local algal densities (Mellina et al. 1995).”

“Zebra mussels attach themselves to unionids by byssal threads. The zebra mussels interfere with the unionid mussels’ ability to open and close their shells, prohibits the unionids’ ability to burrow, and...also consume the algae and suspended sediment that the unionids would otherwise filter from the water.”

From Birnbaum (2011):

“Most of the impacts of zebra mussels in freshwater systems are a direct result of their functioning as ecosystem engineers (Karayayev, *et al*. 2002). An individual zebra mussel can filter one to two liters of water each day; as a result high densities of zebra may cause major shifts in the plankton communities of lakes and rivers. Reductions in phytoplankton numbers and biomass also limit food to fish larvae and other consumers further up the food chain.”

Health and Social Impact

From Crosier and Molloy (2002):

“Increased macrophyte growth can also have a recreational impact. In the summer months of 1994, large amounts of decaying macrophytes washed up along several United States and Canadian shorelines, fouling beaches and causing water quality problems.”

From Benson (2015):

“Zebra mussels are notorious for their biofouling capabilities by colonizing water supply pipes of hydroelectric and nuclear power plants, public water supply plants, and industrial facilities. They colonize pipes constricting flow, therefore reducing the intake in heat exchangers, condensers, firefighting equipment, and air conditioning and cooling systems. Zebra mussel densities were as high as $700{,}000/m^2$ at one power plant in Michigan and the diameters of pipes have been reduced by two-thirds at water treatment facilities. Although there is little information on zebra mussels affecting irrigation, farms and golf courses could be likely candidates for infestations. Navigational and recreational boating can be affected by increased drag due to attached mussels. Small mussels can get into engine cooling systems causing overheating and damage. Navigational buoys have been sunk under the weight of attached zebra mussels. Fishing gear can be fouled if left in the water for long periods. Deterioration of dock pilings has increased when they are encrusted with zebra mussels. Continued attachment of zebra mussel can cause corrosion of steel and concrete affecting its structural integrity.”

4 Global Distribution

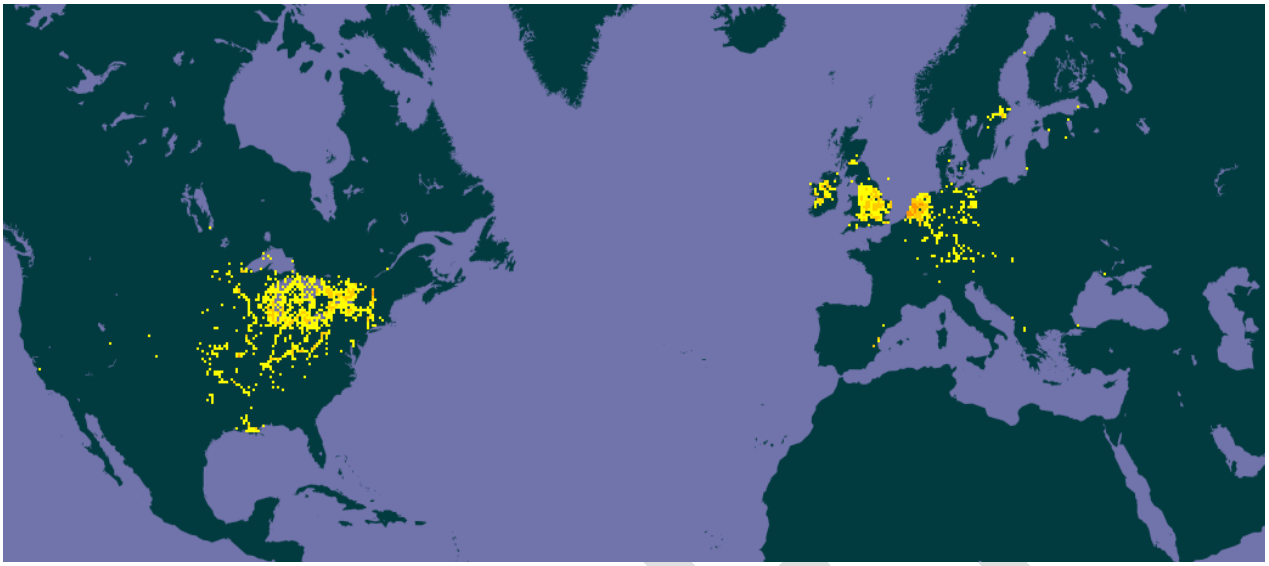

Figure 1. Map showing the worldwide distribution of *Dreissena polymorpha*. Map from GBIF (2015).

5 Distribution within the United States

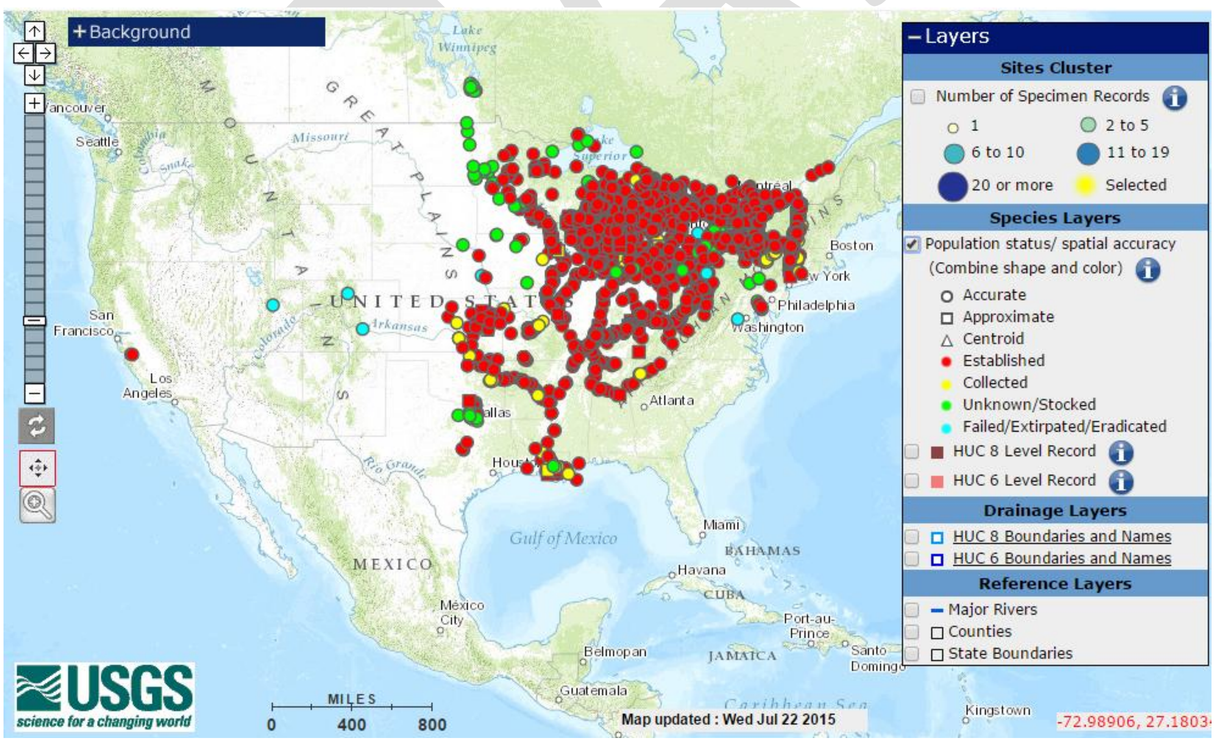

Figure 2. Distribution of *D. polymorpha* in the U.S. Map from Benson (2015).

6 Climate Matching

Summary of Climate Matching Analysis

The climate match (Sanders et al. 2014) was high throughout the East, the Great Lakes, the northern US border, and parts of the Southeast. Medium matches through the plains and northern Rockies. Low matches seen along various areas of the west coast with exceptions in southern California and areas of the Northwest. Climate 6 match indicated that the US has a high climate match. The range for a high climate match is 0.103 and greater; the climate match of *D. polymorpha* is 0.811.

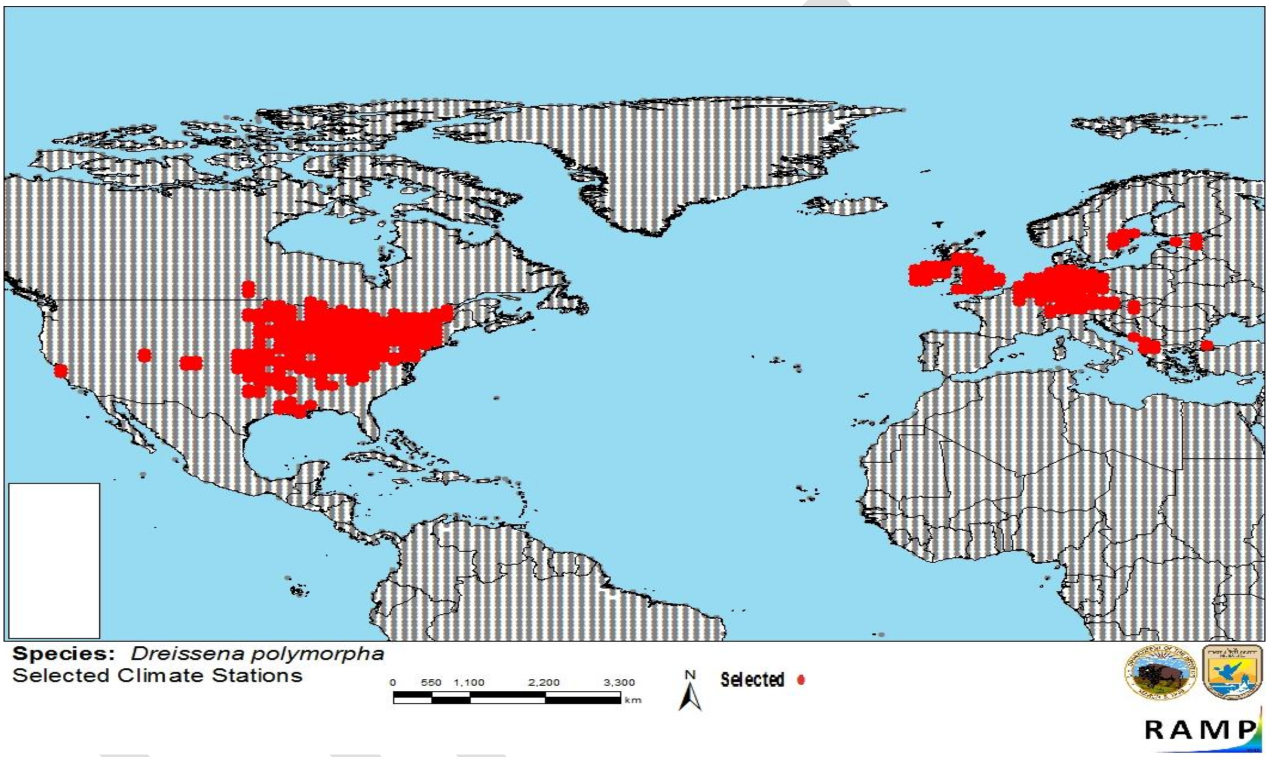

Figure 3. RAMP (Sanders et al. 2014) source map showing weather stations selected as source locations (red) and non-source locations (gray) for *Dreissena polymorpha* climate matching. Source locations from GBIF (2015) and Benson (2015).

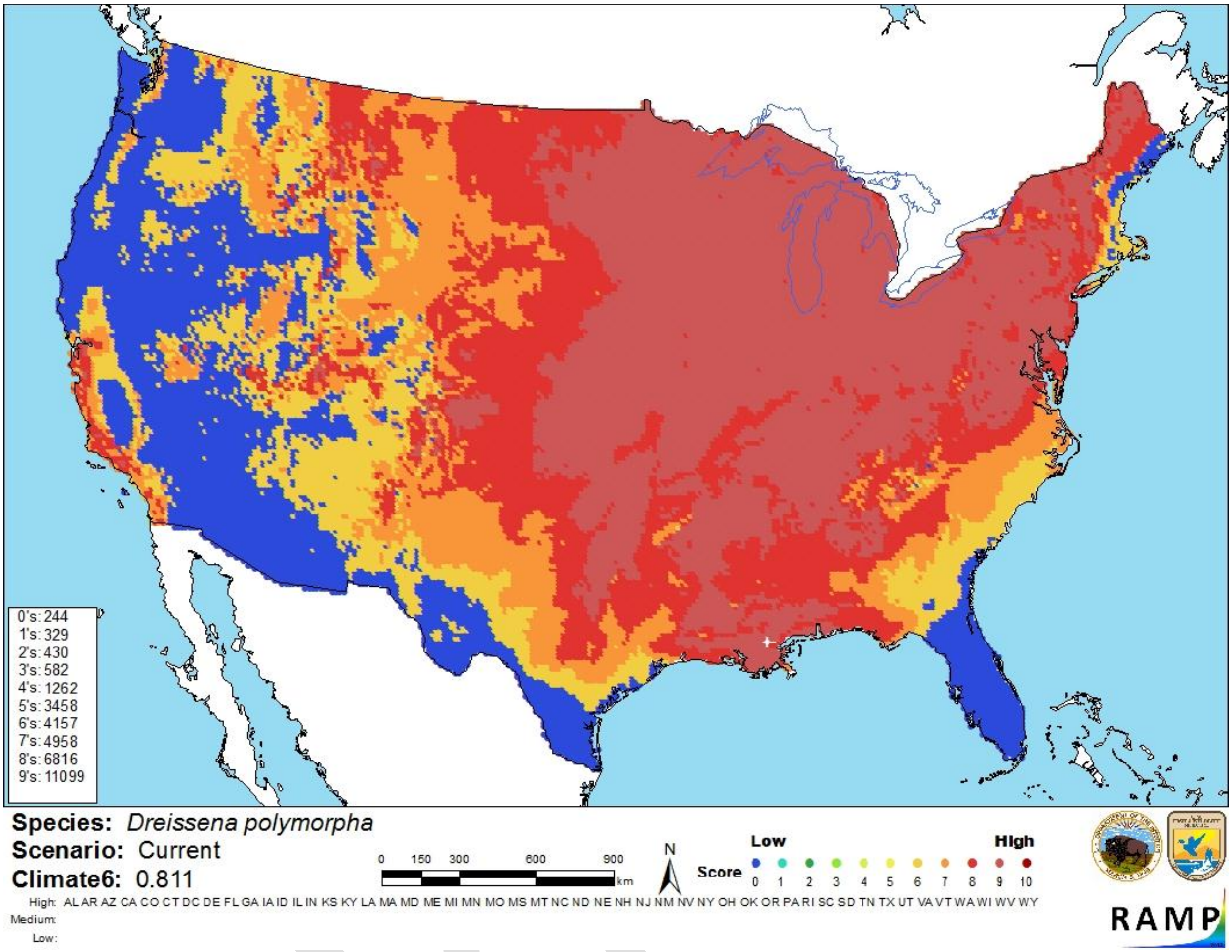

Figure 4. Map of RAMP (Sanders et al. 2014) climate matches for *Dreissena polymorpha* in the continental United States based on source locations reported by GBIF (2015) and Benson (2015). 0= Lowest match, 10=Highest match. Counts of climate match scores are tabulated on the left.

7 Certainty of Assessment

Information on this species is abundant, both on its biology and on the impacts caused by introduction of this species. Certainty of this assessment is high.

8 Risk Assessment

Summary of Risk to the Contiguous United States

Dreissena polymorpha is a euryhaline bivalve mussel native to the Black and Caspian Sea drainages. This species was introduced to the Great Lakes region of the U.S. in the late 1980s via ballast water discharge from ocean vessels and has spread throughout the Northeastern US. using multiple pathways. Its high water filtering capacity poses serious ecological ramifications for native and endangered species including but not limited to: altering biodiversity cascades, impacting water quality, enhancing competition for food reserves, and reducing ecosystem services. Dense *Dreissena* aggregations cling to and clog water transfer systems, boats, and other commercial equipment. Climate change models strongly predict that invasive species such as *Dreissena* may exhibit higher population growth rates due to environmental conditions favorable to both larval and adult forms. The current climate match within the U.S. is high for this highly invasive species, leading to an overall risk rating of high.

Assessment Elements

- **History of Invasiveness (Sec. 3):** High
- **Climate Match (Sec.6):** High
- **Certainty of Assessment (Sec. 7):** High
- **Overall Risk Assessment Category: High**

9 References

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 10.

Benson, A. J., D. Raikow, J. Larson, A. Fusaro, and A. K. Bogdanoff. 2015. *Dreissena polymorpha*. USGS Nonindigenous Aquatic Species Database, Gainesville, Florida. Available: http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=5. (May 2015).

Birnbaum, C. 2011. NOBANIS – invasive alien species fact sheet – *Dreissena polymorpha*. Online Database of the European Network on Invasive Alien Species – NOBANIS. Available: http://www.nobanis.org/globalassets/speciesinfo/d/dreissena-polymorpha/dreissena_polymorpha.pdf. (May 2015).

Ciborowski, J. 2007. Indicator: invasion of zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena bugensis*). U.S. Environmental Protection Agency, Washington, D.C. Available: http://www.epa.gov/med/grosseile_site/indicators/sos/dreissena.pdf. (May 2015).

Crosier, D. M., and D. P. Molloy. 2002. Zebra mussel information system: impacts. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi. Available: http://el.erdc.usace.army.mil/zebra/zmis/zmishelp/increase_in_water_clarity_and_increase_in_macrophyte_coverage_and_biomass.htm. (May 2015).

Delivering Alien Invasive Species Inventories for Europe (DAISIE). 2006. *Dreissena polymorpha*. Available: http://www.europe-aliens.org/pdf/Dreissena_polymorpha.pdf. (June 2015).

Global Biodiversity Information Facility (GBIF). 2015. GBIF backbone taxonomy: *Dreissena polymorpha* (Pallas, 1771). Global Biodiversity Information Facility, Copenhagen. Available: http://www.gbif.org/species/2287072. (July 2015).

Integrated Taxonomic Information System (ITIS). 2015. *Dreissena polymorpha* (Pallas, 1771). Integrated Taxonomic Information System, Reston, Virginia. Available: http://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=81339. (July 2015).

McMahon, R. F. 1996. The physiological ecology of the zebra mussel, *Dreissena polymorpha*, in North America and Europe. American Zoology 36:339-363.

Murphy, T. 2008. *Dreissena polymorpha* (on-line). Animal Diversity Web. Available: http://animaldiversity.org/accounts/Dreissena_polymorpha/. (June 2015).

Ricciardi, A., R. J. Neves, and J. B. Rasmussen. 1998. Impending extinctions of North American freshwater mussels (Unionoida) following the zebra mussel (*Dreissena polymorpha*) invasion. Journal of Animal Ecology 67(4):613-619.

Sanders, S., C. Castiglione, and M. Hoff. 2014. Risk Assessment Mapping Program: RAMP. U.S. Fish and Wildlife Service.

10 References Quoted But Not Accessed

Note: The following references are cited within quoted text within this ERSS, but were not accessed for its preparation. They are included here to provide the reader with more information.

Baker, S. M., and D. J. Hornbach. 1997. Acute physiological effects of zebra mussel (*Dreissena polymorpha*) infestation on two unionid mussels, *Actinonaias ligmentina* and *Amblema plicata*. Canadian Journal of Fisheries and Aquatic Sciences 54:512-519.

Benson, A. J. 2012. The exotic zebra mussel. U.S. Fish and Wildlife Service. Available: http://www.fws.gov/midwest/endangered/clams/zebra.html. (June 2012).

Bruner, K. A., S. W. Fisher, and P. F. Landrum. 1994. The role of the zebra mussel, *Dreissena polymorpha*, in contaminant cycling: II. Zebra mussel contaminant accumulation from algae and suspended particles, and transfer to the benthic invertebrate, *Gammarus fasciatus.* Journal of Great Lakes Research 20:735-750.

Claudi, R., and G. L. Mackie. 1993. Practical manual for zebra mussel monitoring and control. Lewis Publishers, CRC Press, Boca Raton, Florida.

Franz 1992 [cited by Benson 2015; source did not provide full citation]

Gollasch, S., and E. Leppäkoski, editors. 1999. Initial risk assessment of alien species in Nordic coastal waters. Nordic Council of Ministers, Copenhagen.

Hart, R. A., A. C. Miller, and M. Davis. 2001. Empirically derived survival rates of a native mussel, *Amblema plicata*, in the Mississippi and Otter Tail Rivers, Minnesota. American Midland Naturalist 146:254-263.

Holland, R. E. 1993. Changes in planktonic diatoms and water transparency in Hatchery Bay, Bass Island Area, Western Lake Erie since the establishment of the zebra mussel. Journal of Great Lakes Research 19:617-624.

Karayayev, A., L. E. Burlakova, and D. K. Padilla. 2002. Impacts of zebra mussels on aquatic communities and their role as ecosystem engineers. Pages 433-446 *in* E. Leppakoski, S. Gollasch, and S. Olenin, editors. Invasive aquatic species of Europe: distribution, impacts and management. Springer, Dordrecht, Netherlands.

MacIsaac, H. J., C. J. Lonnee, and J. H. Leach. 1995. Suppression of microzooplankton by zebra mussels: importance of mussel size. Freshwater Biology 34:379-387.

Mackie, G. L., W. N. Gibbons, B. W. Muncaster, and I. M. Gray. 1989. The zebra mussel, *Dreissena polymorpha*: a synthesis of European experiences and a preview for North America. Queens Printer for Ontario, Toronto.

Mellina, E., J. B. Rasmussen, and E. L. Mills. 1995. Impact of zebra mussel (*Dreissena polymorpha*) on phosphorus cycling and chlorophyll in lakes. Canadian Journal of Fisheries and Aquatic Sciences 52:2553-2573.

Morton, B. S. 1969. Studies on the biology of *Dreissena polymorpha* Pall. I. General anatomy and morphology. Proceedings of the Malacological Society of London 38:301-321.

Nalepa, T. F., D. J. Hartson, G. W. Gostenik, D. L. Fanslow, and G. A. Lang. 1996. Changes in the freshwater mussel community of Lake St. Clair: from Unionidae to *Dreissena polymorpha* in eight years. Journal of Great Lakes Research 22(2):354-369.

Nichols, K. H., and G. J. Hopkins. 1993. Recent changes in Lake Erie (north shore) phytoplankton: cumulative impacts of phosphorus loading reductions and the zebra mussel introduction. Journal of Great Lakes Research 19:637-647.

North Dakota Game and Fish Department (NDGFD). 2010. NDG&F July 1st Newsletter. Available: http://www.ndhea.org/ndfg/ndgfnewsletter07_01_11.pdf. (June 2012).

Raikow, D. F. 2004. Food web interactions between larval bluegill (*Lepomis macrochirus*) and exotic zebra mussels (*Dreissena polymorpha*). Canandian Journal of Fisheries and Aquatic Science 61:497-504.

Scheffer, M., S. H. Hosper, M. L. Meijer, B. Moss, and E. Jeppesen. 1993. Alternative equilibria in shallow lakes. Trends in Ecology and Evolution 8:275-279.

Schiller, W. 1990. Die Entwicklung der Makrozoobenthosbesied- lung des Rheins in Nordrhein-Westfalen im Zeitraum 1969- 1987. Pages 259-275 *in* R. Kinzelbach, and G. Friedrich, editors. Biologie des Rheins. Limnologie aktuell 1. Fischer, Stuttgart, Germany.

Schloesser, D. W., T. F. Nalepa, and G. L. Mackie. 1996. Zebra mussel infestation of unionid bivalves (Unionidae) in North America. American Zoologist 36:300-310.