

# Quagga Mussel (*Dreissena rostriformis bugensis*) Ecological Risk Screening Summary

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Photo: USGS

## 1 Native Range, and Status in the United States

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### Native Range

From Benson et al. (2014):

“*Dreissena rostriformis bugensis* is indigenous to the Dneiper River drainage of Ukraine and Ponto-Caspian Sea. It was discovered in the Bug River in 1890 by Andrusov, who named the species in 1897 (Mills et al. 1996).”

### Status in the United States

From Benson et al. (2014):

“The quagga mussel is now well established in the lower Great Lakes. This species is found in all of the Great Lakes, but has not been found in great numbers outside of the Great Lakes. This

could be due to a preference for deeper, cooler water found in the Great Lakes region as compared to the zebra mussel (Mills et al. 1996). There is a gradient of dreissenid domination in Lake Erie, with quagga mussels dominating eastern basins and zebra mussels dominating the western basin. The same type of gradient was observed in southern Lake Ontario with quagga mussel dominating the west and zebra dominating the east (Mills et al. 1999). If the native habitat of *D. rostriformis bugensis* is to provide any sort of indicator, the quagga mussel will most likely take over areas where the zebra mussel is now established to become the dominant dreissenid of the Great Lakes (Mills et al. 1996). Indeed, this trend does appear to be occurring in the lower Great Lakes. Mean shell size and biomass increased for both dreissenid species from 1992 and 1995 in southern Lake Ontario (Mills et al. 1999). But the increase was sharper in quagga mussel, and they now dominate in southern Lake Ontario where zebra mussel once did (Mills et al. 1999). At Parker Dam (Lake Havasu) in Arizona, the density was reported at 35,000/sq.m. in 2010 (D. Vigil, pers. comm.).”

“The quagga mussel was first sighted in the **Great Lakes** in September 1989, when one was found near Port Colborne, Lake Erie, though the recognition of the quagga type as a distinct species was not until 1991 (Mills et al. 1996). In August 1991, a mussel with a different genotype was found in a random zebra mussel sample from the Erie Canal near Palmyra, New York, and after confirmation that this mussel was not a variety of *Dreissena polymorpha*, the new species was named "quagga mussel" after the "quagga", an extinct African relative of the zebra (May and Marsden 1992). The quagga mussel has since been found in Lake Michigan, Lake Huron, Lake Erie, Lake Ontario, Lake St. Clair, Saginaw Bay, and throughout the St. Lawrence River north to Quebec City. A 2002 survey of Lake Superior did not detect quagga mussel specimens (Grigorovich et al. 2003), but by 2005 the first quagga mussel was confirmed from Lake Superior in Duluth Superior Harbor (Grigorovich et al. 2008b). A few inland occurrences have been reported in **Iowa, Kentucky, Michigan, Minnesota, New York, Ohio, and Pennsylvania**. In 2004, very limited numbers of quagga mussels were collected from just two of many sample sites on the Ohio River (Grigorovich et al. 2008a).”

“The first sighting of quagga mussels outside the Great Lakes basin was made in the Mississippi River between St. Louis, **Missouri** and Alton, *Illinois* in 1995 (S.J. Nichols, pers. comm.). In January 2007, populations of quagga mussels were discovered in Lake Mead near Boulder City, **Nevada** (W. Baldwin, pers. comm.), and in Lake Havasu and Lake Mohave on the **California/Arizona** border (R. Aikens, pers. comm.). This was an extremely large leap in their range, and cause for much concern to limited water supplies and endangered fishes in the southwestern US. Late in 2007 and early 2008, quagga mussels were discovered in 15 southern **California** reservoirs (D. Norton, pers. comm.). Veligers were identified from six **Colorado** reservoirs (E. Brown, pers. comm.). In Utah, only veligers were collected from Red Fleet Reservoir and just one adult from Sand Hollow Reservoir (L. Dalton, pers. comm.). They are not considered established in Utah. A reservoir in **New Mexico** tested positive for veliger DNA in 2011.”

## Means of Introductions in the United States

From Benson et al. (2014):

“The introduction of *D. rostriformis bugensis* into the Great Lakes appears to be the result of ballast water discharge from transoceanic ships that were carrying veligers, juveniles, or adult mussels. The genus *Dreissena* is highly polymorphic and prolific with high potential for rapid adaptation attributing to its rapid expansion and colonization (Mills et al. 1996). Still, there are other factors that can aid in the spread of this species across North American waters, such as, larval drift in river systems or fishing and boating activities that allow for overland transport or movement between water basins.”

## Remarks

From Benson et al. (2014):

“Hybridization between the two introduced dreissenid species is a concern. Zebra x quagga mussel hybrids were created by pooling gametes collected after exposure to serotonin in the laboratory, indicating that interspecies fertilization may be feasible (Mills et al. 1996). Although, there is evidence for species-specific sperm attractants suggesting that interspecific fertilization may be rare in nature, and if hybridization does occur, these hybrids will constitute a very small proportion of the dreissenid community (Mills et al. 1996).”

## 2 Biology and Ecology

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### Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2014):

“Kingdom Animalia  
Subkingdom Bilateria  
Infrakingdom Protostomia  
Superphylum Lophozoa  
Phylum Mollusca  
Class Bivalvia  
Subclass Heterodonta  
Order Veneroida  
Superfamily Dreissenoidea  
Family Dreissenidae  
Genus *Dreissena*  
Species *Dreissena bugensis*”

“Taxonomic Status: Valid”

### Size, Weight, and Age Range

From ANSIS (2011):

“Small, shell length ranges up to 6 cm”

“Short-lived (3-5 years)”

## **Environment**

From ANSIS (2011):

“Attached to hard substrates in freshwater habitats. May also be found in pipes and grates associated with state, federal, and municipal facilities. Also found on soft sediments in deep waters of Lakes Erie and Ontario.”

From Benson et al. (2014):

“They inhabit freshwater rivers, lakes, and reservoirs. ... The depth at which the mussels live varies depending on water temperature. They are not generally found in lakes near shore in shallow water due to wave action. The quagga mussel can inhabit both hard and soft substrates, including sand and mud, down to depths of 130 m and possibly deeper. The maximum density of quagga mussels in Lake Michigan is at 31-50 m (T. Nalepa, pers. comm.)”

## **Climate/Range**

From Benson et al. (2014):

“In North American populations, they are not known to tolerate salinities greater than 5 ppt (Spidle et al. 1995). Water temperatures of 28°C begin to cause significant mortality, and 32-35°C are considered lethal for *Dreissena* species (Antonov and Shkorbatov 1990 as cited in Mills 1996).”

## **Distribution Outside the United States**

### **Native**

From Benson et al. (2014):

“*Dreissena rostriformis bugensis* is indigenous to the Dnieper River drainage of Ukraine and Ponto-Caspian Sea. It was discovered in the Bug River in 1890 by Andrusov, who named the species in 1897 (Mills et al. 1996).”

### **Introduced**

From CABI (2014):

“The first observation of *D. rostriformis bugensis* outside its native area was reported in 1941, soon after construction of the first reservoir on the Dnieper River (Dnieper Reservoir). Between the 1950s and 1970s, *D. rostriformis bugensis* eventually moved upstream and colonised the whole cascade of reservoirs built on the Dnieper. By 1990-1992, the mussel had spread to the Pripyat River Delta, which is currently its northernmost range within the Dnieper River basin (Mills et al., 1996; Orlova et al., 2005).”

“In 1980, *D. rostriformis bugensis* was recorded for the first time east of its native area, i.e. in the lower stretch of the Don River in Russia, where it supposedly was delivered on the ship hulls

or in ballast water. In 1996, it was found in the middle part of that river (Zhulidov et al., 2005). Construction of the Volga-Don Canal (1948-1952) and extensive ship traffic along it allowed mussels to penetrate into the next large Russian river – the Volga, which drains into the Caspian Sea. Until recently, the initial finding of *D. rostriformis bugensis* in the Volga River system was believed to have occurred in 1992 (Antonov, 1993; Orlova et al., 2004; 2005). However, Zhulidov et al. (2005) re-examined their own archived dreissenid specimens collected between 1979 and 1996 and revealed that *D. rostriformis bugensis* were present in the Volga River system near the Akhtyubinsk City as early as 1981. Between 1994 and 1997, the species was found in the Volga Delta and in the shallows of the Caspian Sea. In 1997, *D. rostriformis bugensis* was recorded in the upper part of the Volga River. By 2000, the mussels colonised seven of the nine large reservoirs of the Volga cascade (Orlova et al., 2004). Around 2001, *D. rostriformis bugensis* penetrated through the shipping canal from the Volga River into the Moscow River (Lvova, 2004).”

“The first record of *D. rostriformis bugensis* west of its native range was in 1988 from the Dniester Reservoir, Ukraine (Shevtsova, 2000), and by 2001 the mussel was already common in the lower part of this river, including the Dniester Estuary (Prof. T. A. Kharchenko, personal communication in Orlova et al., 2005). In 2005, *D. rostriformis bugensis* were observed also in the Moldavian part of the Dniester (Son, 2007). Further spread of *D. rostriformis bugensis* west of its native area was evidenced by two records from the Lower Danube River made in 2004 (Micu and Telembici, 2004) and 2005 (Popa and Popa, 2006) in Romania. The creation of irrigation and shipping canals and ship traffic are considered the main causes for *D. rostriformis bugensis* invasion into the Dniester and Danube Basins (Kharchenko, 1995; Son, 2007). The westernmost European populations of *D. rostriformis bugensis* were revealed in 2006 in the Rhine River Delta, the Netherlands (Molloy et al., 2007), and in 2007 in the Main River, Germany (Van der Velde and Platvoet, 2007). A later paper by Schonenberg and Gittenberger (2008) reports quagga mussel in the Dutch Haringvliet which is now recognised as the westernmost record of this species in Europe. Molloy et al. (2007) suspected that the source of the introduction of *D. rostriformis bugensis* into Western Europe was the Main-Danube Canal re-opened after reconstruction in 1992. As Van der Velde and Platvoet (2007) did not find *D. rostriformis bugensis* in the canal itself, it is likely that population of *D. rostriformis bugensis* in the Netherlands arose as a result of a single long-distance transfer of the propagules from the lower Danube River.”

## **Means of Introduction Outside the United States**

From CABI (2014):

“There are two principal means for the spread of *D. rostriformis bugensis* (Orlova et al., 2005): natural downstream drift of planktonic larvae from an invaded upstream locality; human-mediated transfers.”

“Shipping is considered to be the primary pathway of *D. rostriformis bugensis* introductions into new areas located far outside its native range (Orlova et al., 2005). In Europe, interbasin shipping via man-made canals has resulted in transition of *D. rostriformis bugensis* from the Ponto-Caspian region into the Don and Volga river systems (Orlova et al., 2005) and, recently,

into the rivers Danube (Popa and Popa, 2006), Rhine (Molloy et al., 2007) and Main (Van der Velde and Platvoet, 2007).”

“Having analysed the invasion history of *D. rostriformis bugensis* in Europe, Orlova et al. (2005) concluded that spread of the mussel was triggered by creation of cascades of reservoirs along the Dnieper and Volga rivers.”

## Short description

From Benson et al. (2014):

“*Dreissena rostriformis bugensis* is a small freshwater bivalve mollusk that exhibits many different morphs; yet, there are several diagnostic features that aid in identification. The quagga mussel has a rounded angle, or carina, between the ventral and dorsal surfaces (May and Marsden 1992). The quagga also has a convex ventral side that can sometimes be distinguished by placing shells on their ventral side; a quagga mussel will topple over, whereas a zebra mussel will not (Claudi and Mackie 1994). Color patterns vary widely with black, cream, or white bands; a distinct quagga morph has been found that is pale or completely white in Lake Erie (Marsden et al. 1996). They usually have dark concentric rings on the shell and are paler in color near the hinge. If quaggas are viewed from the front or from the ventral side, the valves are clearly asymmetrical (Domm et al. 1993).”

## Biology

From CABI (2014):

“*D. rostriformis bugensis* is a filter-feeder which consumes food particles suspended in the water column (algae, bacteria, detritus, and micro-zooplankton). Dreissenid mussels have a very complex and effective filtration apparatus (see detailed descriptions in Morton, 1969, 1971; Silverman, 1996a,b; Sprung and Rose, 1988). Water is pumped into the mantle cavity of a mussel through the inhalant siphon, which has many tentacles aiding in the rejection of too large, irritating or sharp particles. Smaller particles enter into the mantle cavity and are strained from the water through a network of cilia located on the surfaces of each of the four gill sheets. The cilia gradually sweep the particles anteriorly towards the two labial palps located on each side of the mouth. Cilia of the labial palps are able to sort the particles into edible and inedible. Particles of an appropriate size (usually 5-35  $\mu\text{m}$ ) and palatability are then moved into the mouth, whereas rejected particles are bound in mucus and moved to the edge of the mantle. The mucoid-bound particle pellets are called pseudofaeces or agglutinates. They are ejected from the mantle cavity through the excurrent siphon by rapid closing of the shell valves.”

“Numerous field studies have shown that spawning in dreissenids usually does not start if water temperature is below 12°C, and that the mass release of gametes takes place in June-August (e.g., Walz, 1978; Sprung, 1987; Borchering, 1991; Nichols, 1996; Karatayev et al., 1997).”

From GISD (2011):

“After fertilisation veligers (pelagic microscopic larvae) develop within a few days and soon acquire minute bivalve shells.”

“Free-swimming veligers drift with the currents for three to four weeks, feeding using their hair-like cilia while trying to locate suitable substrata to settle and secure byssal threads. Mortality in this transitional stage from planktonic veliger to settled juveniles may exceed 99% (Stanczykowska 1977, in Bially & MacIsaac 2000).”

“Macrophytes, mussel colonies and pebbles were found to be more suitable substrates for settling than gravel, sand or mud (Lewandowski 1982, in Bially & MacIsaac 2000).”

## Human uses

From GISD (2011):

“Because they are long-lived and sessile, quagga mussels can be used as bioindicators of hazardous substances such as radionuclides (Lubianov 1972, in Orlova 2009).”

## Diseases

From CABI (2014):

“The most severe parasitic disease is likely to be caused by the trematode *Bucephalus polymorphus*, which can substantially destruct the gonads of a mussel host (Molloy et al., 1997; Laruelle et al., 2002).”

## Threat to humans

From CABI (2014):

“The invasion of *D. rostriformis bugensis* into numerous European and North American waterbodies has resulted in a number of adverse impacts, both environmental and economic. Due to their ability to colonise hard surfaces, these mussels become a major fouling problem for raw water-dependent infrastructures, causing damage and increased operating expenses. The mussels invade and clog water-intake pipes and water filtration systems of the municipalities and electric generating plants, fire prevention systems, navigation dams, docks, buoys, hulls of the commercial and recreational vessels, etc. (Molloy, 1998). In the USA alone, the estimated costs associated with *Dreissena* total about 1 billion dollars per year (Pimentel et al., 2005).”

## 3 Impacts of Introductions

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From Benson et al. (2014):

“Quaggas are prodigious water filterers, removing substantial amounts of phytoplankton and suspended particulate from the water. As such, their impacts are similar to those of the zebra mussel. By removing the phytoplankton, quaggas in turn decrease the food source for zooplankton, therefore altering the food web.”

“Many of the potential impacts of *Dreissena* are unclear due to the limited time scale of North American colonization. Nonetheless, it is clear that the genus *Dreissena* is highly polymorphic and has a high potential for rapid adaptation to extreme environmental conditions by the evolution of allelic frequencies and combinations, possibly leading to significant long-term

impacts on North American waters (Mills et al. 1996). *Dreissena rostriformis bugensis* lacks the keeled shape that allows *D. polymorpha* to attach so tenaciously to hard substrata; though, *D. rostriformis bugensis* is able to colonize hard and soft substrata (Mills et al. 1996). The ability to colonize different substratas could suggest that *D. rostriformis bugensis* is not limited to deeper water habitats and that it may inhabit a wider range of water depths where they have been found at depths up to 130 m in the Great Lakes (Mills et al. 1996, Claxton and Mackie 1998).”

“*Dreissena* have a negative impact on the water column due to increased filtration of water causing water transparency, decreases in mean chlorophyll a concentrations, and accumulation of pseudofeces (Claxton et al. 1998).”

“Water clarity increases light penetration causing a proliferation of aquatic plants that can change species dominance and alter the entire ecosystem.”

“The pseudofeces that is produced from filtering the water accumulates and creates a foul environment. As the waste particles decompose, oxygen is used up, and the pH becomes very acidic and toxic byproducts are produced. In addition, quagga mussels accumulate organic pollutants within their tissues to levels more than 300,000 times greater than concentrations in the environment and these pollutants are found in their pseudofeces, which can be passed up the food chain, therefore increasing wildlife exposure to organic pollutants (Snyder et al. 1997).”

From GISD (2011):

“*D. bugensis* causes changes in the structural characteristics of zooplankton including total abundance, biomass and species composition, specifically, leading to an inverse relationship between zooplankton abundance/biomass and density of *Dreissena* mussels (Grigorovich & Shevtsova, 1995). *Dreissena* infestations have caused upwards of 95% reduction in unionid numbers and extirpated eight species of unionids in some areas of the Great Lakes (Schloesser et al. 1998; Schloesser & Masteller 1999). Individuals attach themselves to the shells of other mussels, forming encrusting mats many shells thick (10-30mm).”

“*Dreissena* negatively affects benthic invertebrate communities, especially filter-feeding or deep-dwelling invertebrates that rely on detrital rain (Dermott and Munawar 1993, Strayer et al. 1998, Johannsson et al. 2000, in Haynes et al. 2005). Predicting benthic invertebrate community response to a change in nutrient levels is very difficult, and the potential synergistic effects of nutrient alterations and exotics such as *Dreissena* are complex (Haynes et al. 2005).”

“**Location Specific Impacts:**”

“**Presque Isle Bay** (North America)

Reduction in native biodiversity: In Presque Isle Bay on Lake Erie, dreissenid mussels surveyed sites experienced 100% unionid mortality after it was discovered that the invasive mussels were present. It is believed there are natural refugia areas that the mussels will be unable to invade but the impacts are still severe (Schloesser & Masteller 1999).”

**“Lake Erie (North America)**

Competition: *Dreissena bugensis* competes with and displaces native bivalves in Lake Erie (Bially & MacIsaac, 2000).

Reduction in native biodiversity: In Lake Erie's eastern basin, dense colonies of *Dreissena bugensis* have infested profundal areas up to depths of 55m (Roe and MacIsaac 1997). Although some meiofaunal species have benefited from the presence of *D. bugensis* in the profundal zone, burrowing amphipod *Diporeia hoyi* numbers have declined sharply (Dermott and Kerec 1997; Mills et al 1999).”

**“Lake Michigan (North America)**

Interaction with other invasive species: *Dreissena bugensis* has a potential role in expanding the depth range of *Echinogammarus ischnus* (Nalepa et al 2001).

Modification of natural benthic communities: With the loss of *Diporeia* and increase in *D. bugensis*, the benthic community has become a major energy sink rather than a pathway to upper trophic levels. With this replacement of dominant taxa, we estimate that the relative benthic energy pool increased from 17 to 109 kcal m<sup>2</sup> between 1994 /1995 and 2005, and to 342 kcal m<sup>2</sup> by 2007. It is projected that previously observed impacts on fish populations will continue and become more pronounced as the *D. bugensis* population continues to expand in deeper waters (Nalepa et al, 2009).

Modification of nutrient regime: *Dreissena bugensis* will likely cause other changes to the off-shore food web (Nalepa et al 2001). With *D. bugensis* now present and poised to expand in the offshore region, the rate of decline in *Diporeia* will likely increase, and the lake area devoid of this important fish-food organism will become more extensive (Nalepa et al 2001).

Reduction in native biodiversity: *Dreissena bugensis* populations growing in Lake Michigan, which are replacing *D. polymorpha* in locations, also contribute to the reduction of native amphipod *Diporeia spp.* (Nalepa et al, 2009).”

**“Lake Ontario (North America)**

Modification of natural benthic communities: The establishment of *Dreissena bugensis* and *D. polymorpha* coincided with a drastic decline of native amphipod *Diporeia spp.* (Owens & Dittman, 2003).

Reduction in native biodiversity: In response to the disappearance of *Diporeia spp.*, believed to have resulted from the introduction of *Dreissena bugensis* and *D. polymorpha*, populations of two native benthivores, slimy sculpin and lake whitefish, collapsed in eastern Lake Ontario, perhaps due in part to starvation, because *Diporeia* was their principal prey (Owens & Dittman, 2003).”

**“St. Lawrence River (North America)**

Fouling: Locations of St. Lawrence River where *Dreissena bugensis* occurred in densities of 4,000-20,000/m<sup>2</sup> resulted in 90-100% native unionid mortality. *D. bugensis* colonize unionid bivalves in high densities. Data suggests that once *Dreissena* mass is equal to or exceeds that of the bivalve, it will be extirpated (Ricciardi et al, 1996).”

**“Kakhovka Canal (Ukraine)**

Modification of nutrient regime: Results of investigations concluded that structural characteristics of zooplankton including total abundance, biomass and species composition are

lower in the areas supporting massive populations of *Dreissena* in the Main Kakhovka Canal. There is an inverse relationship between zooplankton abundance and biomass and density of *Dreissena* mussels, which exert pressure on zooplankton (Grigorovich and Shevtsova, 1995).”

“**Detroit River** (United States (USA))

Reduction in native biodiversity: The present study documents extensive and severe mortality of unionids caused by dreissenid mussel infestations in the Detroit River of the Great Lakes. Infestation caused a 95% reduction in the number and extirpated eight species of unionids between 1986 (when zebra mussels were first introduced into the system) and 1992/1994. This study, and others, suggest that: (1) high mortality of unionids can occur between 4 and 6 yrs. after initial invasion by dreissenids or up to 8 yrs. depending on water current patterns; (2) species in the subfamilies Anodontinae and Lampsilinae were more vulnerable to infestation than species of Ambleminae; (3) numbers of individuals of commonly found species declined more than numbers of individuals of uncommonly found species; and (4) numbers of uncommonly found taxa declined more than numbers of commonly found taxa (Schloesser et al 1998).”

“**Michigan** (United States (USA))

Reduction in native biodiversity: A sampling of the Detroit River in 1982-1983 before the introduction of *Dreissena bugensis* and *Dreissena polymorpha* resulted in 97% live unionids of 20 different species, whereas a sampling in 1992 after the introduction of the two *Dreissena spp.* resulted in only 10% live unionids of only 13 different species. Surveys of native freshwater mussels along main channels of the Detroit River from 1992-1994 showed that unionids had been extirpated from all but four sites in the upper reaches of the river due to impacts of dreissenid mussels (Schloesser et al, 1998; Schloesser et al, 2006).”

“**Mississippi River** (United States (USA))

Fouling: Diversity and densities of native mussels in decline (Ricciardi et al, 1996, Schloesser et al. 1996).”

“**Missouri River** (United States (USA))

Fouling: Diversity and densities of native mussels in decline (Ricciardi et al, 1996, Schloesser et al. 1996).”

From CABI (2014):

“The filtering activity of *Dreissena* leads to increased water transparency and light penetration, decreased concentrations of seston and organic matter, decreased biochemical oxygen demand, and increased concentrations of ammonia, nitrates, and phosphates (see Karatayev et al., 1997, 2002; Vanderploeg et al., 2002; Burlakova et al., 2005). As *D. rostriformis bugensis* has higher filtration rate than *D. polymorpha* (Diggins, 2001), the former are likely to have greater environmental impacts associated with filtration than the latter.”

## 4 Global Distribution

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Figure 1. Global distribution of *D. rostriformis bugensis*. Map from GBIF (2015).

## 5 Distribution within the United States

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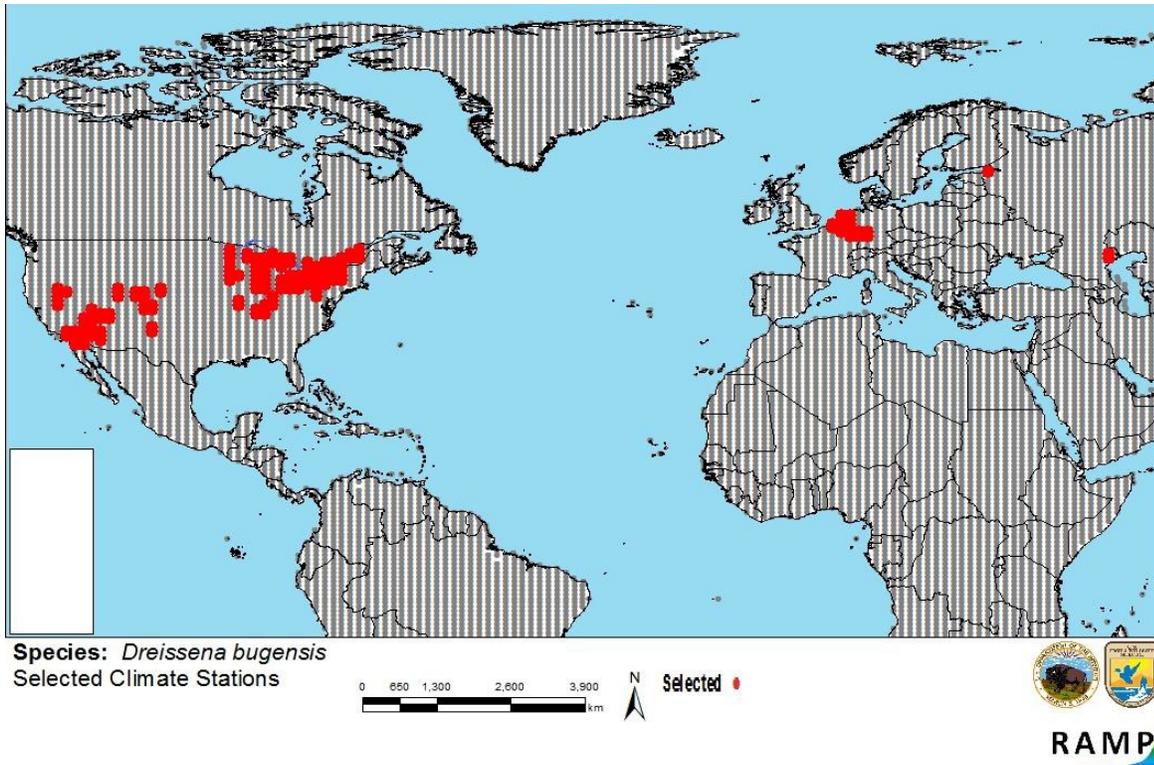


Figure 2. Distribution of *D. rostriformis bugensis*. Map from Benson et al. (2014).

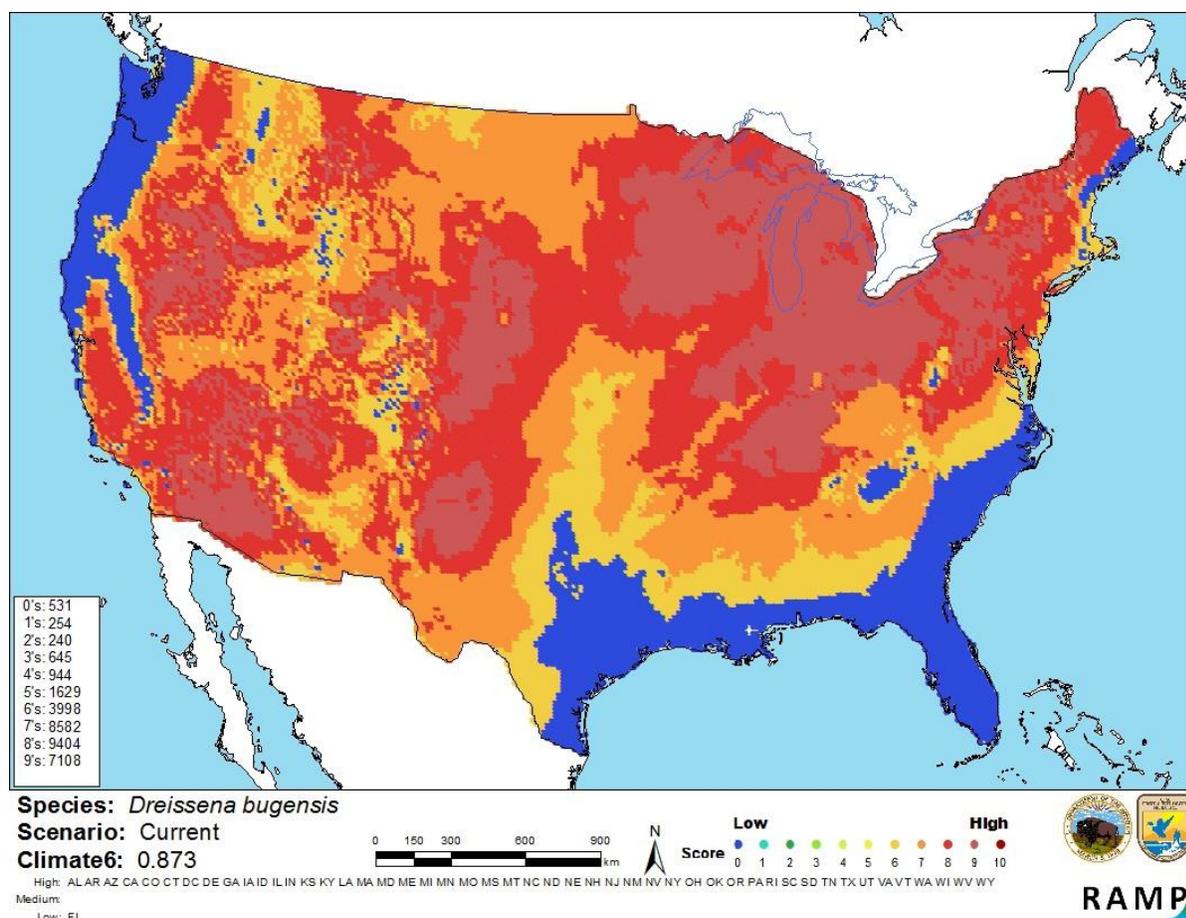
## 6 Climate Matching

### Summary of Climate Matching Analysis

The climate match (Sanders et al. 2014) was high throughout New England and the Great Lakes States, as well as southern California, Nevada, Arizona and much of the Mountain West. Medium and low matches covered the Gulf Coast, Florida and the Northwest. Climate 6 match indicated that the U.S. has a high climate match. The range for a high climate match is 0.103 and greater; climate match of *Dreissena rostriformis bugensis* is 0.873.



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



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

## 7 Certainty of Assessment

The biology and ecology of *D. rostriformis bugensis* are well-known. Negative impacts from introductions and spread of this species are adequately documented in the scientific literature. No further information is needed to evaluate the negative impacts the species is having where introduced. Certainty of this assessment is high.

## 8 Risk Assessment

### Summary of Risk to the Continental United States

Establishment and impacts in the United States are occurring. Spreading of this nonindigenous species is likely between watersheds, where transportation of boats and other watercraft is common. *D. rostriformis bugensis* can profoundly modify ecosystem characteristics through cascading effects of its water filtration behavior. Thick encrustations of mussels form on man-made structures or within raw water systems, affecting operation and efficiency. *D. bugensis* can have major detrimental impacts on recreational and commercial shipping/boating as well as on water-using industries, potable water treatment plants, and electric power stations. Major impacts have been reported for native species in the Great Lakes. Overall risk assessment is high.

## Assessment Elements

- History of Invasiveness (Sec. 3): High**
- Climate Match (Sec.6): High**
- Certainty of Assessment (Sec. 7): High**
- Remarks/Important additional information:** Reported to occasionally hybridize with zebra mussels.
- Overall Risk Assessment Category: High**

## 9 References

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

- Aquatic Nuisance Species Information System (ANSIS). 2011. *Dreissena rostriformis bugensis*. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi. Available: <http://el.erd.c.usace.army.mil/ansrp/ANSIS/ansishelp.htm>. (February 2011).
- Benson, A. J., M. M. Richerson, E. Maynard, J. Larson, A. Fusaro, and A. K. Bogdanoff. 2014. *Dreissena rostriformis bugensis*. USGS Nonindigenous Aquatic Species Database, Gainesville, Florida. Available: <http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=95>. (September 2014).
- CABI. 2014. *Dressena rostriformis bugensis* (Quagga Mussel) [original text by S. Mastitsky]. CAB International, Wallingford, UK. Available: <http://www.cabi.org/isc/datasheet/107770>. (September 2014).
- Global Biodiversity Information Facility (GBIF). 2015. GBIF backbone taxonomy: *Dreissena rostriformis bugensis* Andrusov, 1897. Global Biodiversity Information Facility, Copenhagen. Available: <http://www.gbif.org/species/4371624>. (June, July 2015).
- Global Invasive Species Database (GISD). 2011. *Dressena rostriformis bugensis*. IUCN Invasive Species Specialist Group, Gland, Switzerland. Available from: <http://www.issg.org/database/species/ecology.asp?si=918&fr=1&sts=&lang=EN> (February 2011).
- Integrated Taxonomic Information System (ITIS). 2014. *Dressena rostriformis bugensis*. Integrated Taxonomic Information System, Reston, Virginia. Available: <http://www.itis.gov/servlet/SingleRpt/SingleRpt>. (September 2014).
- 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.**

- Antonov, P. I. 1993. About invasion of bivalve mollusc *Dreissena bugensis* (Andr.) into the Volga River reservoirs. Pages 52-53 in Abstracts of the international conference “Ecological problems of large rivers’ basins”, Togliatti, Russia, 6-10 September 1993. IEVB RAS Press, Togliatti, Russia.

- Antonov and Shkorbatov 1990 [cited by Benson et al. 2014; source did not provide full citation]
- Bially, A., and H. J. MacIsaac. 2000. Fouling mussels (*Dreissena spp.*) colonize soft sediments in Lake Erie and facilitate benthic invertebrates. *Freshwater Biology* 43:85-97.
- Borcherding, J. 1991. The annual reproductive cycle of the freshwater mussel *Dreissena polymorpha* Pallas in lakes. *Oecologia* 87:208-218.
- Burlakova, L. E., A. Y. Karatayev, and D. K. Padilla. 2005. Functional changes in benthic freshwater communities after *Dreissena polymorpha* (Pallas) invasion and consequences for filtration. Pages 263-275 in R. Dame, and S. Olenin. *The comparative roles of suspension feeders in ecosystems*. NATO Science Series IV: Earth and Environmental Sciences, volume 47. Springer, The Netherlands.
- Claudi, R., and G. L. Mackie. 1994. Practical manual for zebra mussel monitoring and control. Chapter 1. Biology of the zebra mussel. Lewis Publishers, CRC Press, Boca Raton, Florida.
- Claxton, W. T., and G. L. Mackie. 1998. Seasonal and depth variations in gametogenesis and spawning of *Dreissena polymorpha* and *Dreissena bugensis* in eastern Lake Erie. *Canadian Journal of Zoology* 76:2010-2019.
- Claxton, W. T., A. B. Wilson, G. L. Mackie, and E. G. Boulding. 1998. A genetic and morphological comparison of shallow- and deep-water populations of the introduced dreissenid bivalve *Dreissena bugensis*. *Canadian Journal of Zoology* 76(7):1269-1276.
- Dermott, R., and D. Kerec. 1997. Changes to the deepwater benthos of eastern Lake Erie since the invasion of *Dreissena*: 1979–1993. *Canadian Journal of Fisheries and Aquatic Sciences* 54:922–930.
- Dermott, R., and M. Munawar. 1993. Invasion of Lake Erie offshore sediments by *Dreissena*, and its ecological implications. *Canadian Journal of Fisheries and Aquatic Sciences* 50:2298–2304.
- Diggins, T. P. 2001. A seasonal comparison of suspended sediment filtration by quagga (*Dreissena bugensis*) and zebra (*D. polymorpha*) mussels. *Journal of Great Lakes Research* 27(4):457-466.
- Domm, S., R. W. McCauley, and E. Kott. 1993. Physiological and taxonomic separation of two dreissenid mussels in the Laurentian Great Lakes. *Canadian Journal of Fisheries and Aquatic Science* 50:2294-2298.
- Grigorovich, I. A., T. R. Angradi, and C. A. Stepien. 2008a. Occurrence of the quagga mussel (*Dreissena bugensis*) and the zebra mussel (*Dreissena polymorpha*) in the Upper Mississippi River System. *Journal of Freshwater Ecology* 23(3):429-435.

- Grigorovich, I. A., J. R. Kelly, J. A. Darling, and C. W. West. 2008b. The quagga mussel invades the Lake Superior Basin. *Journal of Great Lakes Research* 34(2):342-350.
- Grigorovich, I. A., A. V. Korniushev, D. K. Gray, I. C. Duggan, R. I. Colautti, and H. J. MacIsaac. 2003. Lake Superior: an invasion coldspot? *Hydrobiologia* 499:191-210.
- Grigorovich, I. A., and L. V. Shevtsova. 1995. Effect of *Dreissena* mussels on the distribution of zooplankton as exemplified by the Main Kakhovka Canal. Proceedings of The Fifth International Zebra Mussel and Other Aquatic Nuisance Organisms Conference, Toronto, Canada.
- Haynes, J. M., N. A. Tisch, C. M. Mayer, and R. S. Rhyne. 2005. Benthic macroinvertebrate communities in southwestern Lake Ontario following invasion of *Dreissena* and *Echinogammarus*: 1983 to 2000. *Journal of the North American Benthological Society* 24(1):148-167.
- Johannsson, M. W., P. Keyser, K. Sritunyalucksana, and K. Sonderhall. 2000. Crustacean haemocytes and haematopoiesis. *Aquaculture* 191:45-52.
- Karatayev, A. Y., L. E. Burlakova, and D. K. Padilla. 1997. The effects of *Dreissena polymorpha* (Pallas) invasion on aquatic communities in Eastern Europe. *Journal of Shellfish Research* 16:187-203.
- Karatayev, A. Y., 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. Leppäkoski, S. Gollasch, and S. Olenin, editors. *Invasive aquatic species of Europe: distribution, impacts and management*. Kluwer Academic Publishers, Dordrecht, The Netherlands.
- Kharchenko, T. A. 1995. *Dreissena*: range, ecology, fouling impacts. *Hydrobiologicheskii Zhurnal* 31(3):3-20.
- Laruelle, F., D. P. Molloy, and V. A. Roitman. 2002. Histological analysis of trematodes in *Dreissena polymorpha*: their location, pathogenicity, and distinguishing morphological characteristics. *Journal of Parasitology* 88(5):856-863.
- Lewandowski, K. 1982. The role of early developmental stages, in the dynamics of *Dreissena polymorpha* (Pall.) (Bivalvia) populations in lakes. II. Settling of larvae and the dynamics of numbers of settled individuals. *Ekologia Polski* 30:223-286.
- Lubianov 1972 [cited by GISD 2011; source did not provide full citation]
- Lvova, A. A. 2004. On invasion of *Dreissena bugensis* (Bivalvia, Dreissenidae) in the Ucha Reservoir (Moscow oblast) and the Moscow River. *Zoologicheskii Zhurnal* 83:766-768.
- Marsden, J. E., A. P. Spidle, and B. May. 1996. Review of genetic studies of *Dreissena* spp. *American Zoology* 36:259-270.

- May, B., and J. E. Marsden. 1992. Genetic identification and implications of another invasive species of dreissenid mussel in the Great Lakes. *Canadian Journal of Fisheries and Aquatic Science* 49:1501-1506.
- Micu, D., and A. Telembici. 2004. First record of *Dreissena bugensis* (Andrusov 1897) from the Romanian stretch of River Danube. Abstracts of the International Symposium of Malacology, August 19–22, 2004, Sibiu, Romania.
- Mills, E. L., G. Rosenberg, A. P. Spidle, M. Ludyanskiy, Y. Pligin, and B. May. 1996. A review of the biology and ecology of the quagga mussel (*Dreissena bugensis*), a second species of freshwater dreissenid introduced to North America. *American Zoology* 36:271-286.
- Mills, E. L., J. R. Chrisman, B. Baldwin, R. W. Owens, R. O'Gorman, T. Howell, E. F. Roseman, and M. K. Raths. 1999. Changes in the dreissenid community in the Lower Great Lakes with emphasis on Southern Lake Ontario. *Journal of Great Lakes Research* 25(1):187-197.
- Molloy, D. P. 1998. The potential for using biological control technologies in the management of *Dreissena spp.* *Journal of Shellfish Research* 17(1):177-183.
- Molloy, D. P., A. bij de Vaate, T. Wilke, and L. Giamberini. 2007. Discovery of *Dreissena rostriformis bugensis* (Andrusov 1897) in Western Europe. *Biological Invasions* 9(7):871-874.
- Molloy, D. P., A. Y. Karatayev, L. E. Burlakova, D. P. Kurandina, and F. Laruelle. 1997. Natural enemies of zebra mussels: predators, parasites and ecological competitors. *Reviews in Fisheries Science* 5(1):27-97
- Morton, B. S. 1969. Studies on the biology of *Dreissena polymorpha* Pall. General anatomy and morphology. *Proceedings of the Malacological Society of London* 38:301-321.
- Morton, B. 1971. Studies on the biology of *Dreissena polymorpha* Pall. Some aspects on the biology of filter-feeding and the effect of microorganisms upon the rate of filtration. *Proceedings of the Malacological Society of London* 39:289-301.
- Nalepa, T. F., D. W. Schloesser, S. A. Pothoven, D. W. Hondorp, D. L. Fanslow, M. L. Tuchman, and G. W. Fleischer. 2001. First finding of the amphipod *Echinogammarus ischnus* and the mussel *Dreissena bugensis* in Lake Michigan. *Journal of Great Lakes Research*. 27(3):384-391.
- Nalepa, T. F., D. L. Fanslow, and G. A. Lang. 2009. Transformation of the offshore benthic community in Lake Michigan: recent shift from the native amphipod *Diporeia spp.* to the invasive mussel *Dreissena rostriformis bugensis*. *Freshwater Biology* 54(3):466-479.

- Nichols, S. J. 1996. Variations in the reproductive cycle of *Dreissena polymorpha* in Europe, Russia and North America. *American Zoologist* 36:311-325.
- Orlova, M. I. 2009. Zebra and quagga mussels in the inland waters of European Russia and adjacent countries. Pages 371-386 in G. L. Mackie, and R. Claudi. *Monitoring and control of macrofouling mollusc in freshwater systems*. CRC Press, Boca Raton, Florida.
- Orlova, M. I., J. R. Muirhead, P. I. Antonov, G. K. Shcherbina, Y. I. Starobogatov, G. I. Biochino, T. W. Therriault, and H. J. MacIsaac. 2004. Range expansion of quagga mussels *Dreissena rostriformis bugensis* in the Volga River and Caspian Sea basin. *Aquatic Ecology* 38:561-573.
- Orlova, M. I., T. W. Therriault, P. I. Antonov, and G. K. Shcherbina. 2005. Invasion ecology of quagga mussels (*Dreissena rostriformis bugensis*): a review of evolutionary and phylogenetic impacts. *Aquatic Ecology* 39(4):401-418.
- Owens, R. W., and D. E. Dittman. 2003. Shifts in the diets of slimy sculpin (*Cottus cognatus*) and lake whitefish (*Coregonus clupeaformis*) in Lake Ontario following the collapse of the burrowing amphipod *Diporeia*. *Aquatic Ecosystem Health & Management* 6(3):311-323.
- Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52(3):273-288.
- Popa, O. P., and L. O. Popa. 2006. The most westward European occurrence point for *Dreissena bugensis* (Andrusov 1897). *Malacologica Bohemoslovaca* 5:3-5.
- Ricciardi, A., F. G. Whoriskey, and J. B. Rasmussen. 1996. Impact of the *Dreissena* invasion on native unionid bivalves in the upper St. Lawrence River. *Canadian Journal of Fisheries and Aquatic Sciences* 53(6):1434-1444.
- Roe, S. L., and H. J. MacIsaac. 1997. Deepwater population structure and reproductive state of quagga mussels (*Dreissena bugensis*) in Lake Erie. *Canadian Journal of Fisheries and Aquatic Sciences* 54:2428-2433.
- Schloesser, D. W., W. P. Kovalak, G. D. Longton, K. L. Ohnesorg, and R. D. Smithee. 1998. Impact of zebra and quagga mussels (*Dreissena spp.*) on freshwater unionids (Bivalvia: Unionidae) in the Detroit River of the Great Lakes. *American Midland Naturalist* 140(2):299-313.
- Schloesser, D. W., and E. C. Masteller. 1999. Mortality of unionid bivalves Mollusca associated with dreissenid mussels. *Northeastern Naturalist* 6(4):341.
- Schloesser, D. W., J. L. Metcalfe-Smith, W. P. Kovalak, G. D. Longton, and R. D. Smithee. 2006. Extirpation of freshwater mussels (Bivalvia: Unionidae) following the invasion of

- dreissenid mussels in an interconnecting river of the Laurentian Great Lakes. *American Midland Naturalist* 155(2):307-320.
- Schloesser, D. W., T. F. Nalepa, and G. L. Mackie. 1996. Zebra mussel infestation of unionid bivalves (Unionidae) in North America. *American Zoologist* 36(3):300-310.
- Schonenberg, D. B., and A. Gittenberger. 2008. The invasive quagga mussel *Dreissena rostriformis bugensis* (Andrusov, 1879) (Bivalvia: Dreissenidae) in the Dutch Haringvliet, an enclosed freshwater Rhine-Meuse estuary, the westernmost record for Europe. *Basteria* 72:345-352.
- Shevtsova, L. V. 2000. Establishment of populations of bivalve molluscs of the genus *Dreissena* in the Dniester River. Pages 160-161 in Y. I. Starobogatov, and E. N. Egorova, editors. *Molluscs: problems of taxonomy, ecology and phylogeny*. St. Petersburg, Russia.
- Silverman, H., J. W. Lynn, E. C. Achberger, and T. H. Dietz. 1996a. Gill structure in zebra mussels: bacterial-sized particle filtration. *American Zoologist* 36:373-384.
- Silverman, H., J. W. Lynn, and T. H. Dietz. 1996b. Particle capture by the gills of *Dreissena polymorpha*: structure and function of latero-frontal cirri. *Biological Bulletin* 191:42-54.
- Snyder, F. L., M. B. Hilgendorf, and D. W. Garton. 1997. Zebra mussels in North America: the invasion and its implications. Ohio Sea Grant, Ohio State University, Columbus, OH. Available: [http://ohioseagrant.osu.edu/\\_documents/publications/FS/FS-045%20Zebra%20mussels%20in%20North%20America.pdf](http://ohioseagrant.osu.edu/_documents/publications/FS/FS-045%20Zebra%20mussels%20in%20North%20America.pdf).
- Son, M. O. 2007. Native range of the zebra mussel and quagga mussel and new data on their invasions within the Ponto-Caspian Region. *Aquatic Invasions* 2(3):174-184.
- Spidle, A. P., E. L. Mills, and B. May. 1995. Limits to tolerance of temperature and salinity in the quagga mussel (*Dreissena bugensis*) and the zebra mussel (*Dreissena polymorpha*). *Canadian Journal of Fisheries and Aquatic Sciences* 52:2108-2119.
- Sprung, M. 1987. Ecological requirements of developing *Dreissena polymorpha* eggs. *Archiv für Hydrobiologie Supplement* 79:69-86.
- Sprung, M., and U. Rose. 1988. Influence of food size and food quantity on the feeding of the mussel *Dreissena polymorpha*. *Oecologia* 77:526-532.
- Stanczykowska, A. 1977. Ecology of *Dreissena polymorpha* (Pallas) (Bivalvia) in lakes. *Polish Archives of Hydrobiology* 24:461-530.
- Strayer, D. L., L. C. Smith, and D. C. Hunter. 1998. Effects of the zebra mussel (*Dreissena polymorpha*) invasion on the macrobenthos of the freshwater tidal Hudson River. *Canadian Journal of Zoology* 76(3):419-425.

- Vanderploeg, H. A., T. F. Nalepa, D. J. Jude, E. L. Mills, K. T. Holeck, J. R. Liebig, I. A. Grigorovich, and H. Ojaveer. 2002. Dispersal and emerging ecological impacts of Ponto-Caspian species in the Laurentian Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 59:1209-1228.
- Van der Velde, G., and D. Platvoet. 2007. Quagga mussels *Dreissena rostriformis bugensis* (Andrusov, 1897) in the Main River (Germany). *Aquatic Invasions* 2(3):261-264.
- Walz, N. 1978. The energy balance of the freshwater mussel *Dreissena polymorpha* Pallas in laboratory experiments and in Lake Constance II. Reproduction. *Archiv für Hydrobiologie Supplement* 55:106-119.
- Zhulidov, A. V., D. A. Zhulidov, D. F. Pavlov, T. F. Nalepa, and T. Yu. Gurtovaya. 2005. Expansion of the invasive bivalve mollusk *Dreissena bugensis* (quagga mussel) in the Don and Volga River Basins: revisions based on archived specimens. *Ecohydrology and Hydrobiology* 5(2):127-133.