Golden Mussel (*Limnoperna fortunei*)

Ecological Risk Screening Summary

U.S. Fish & Wildlife Service, March 2020
Revised, April 2020
Web Version, 10/4/2021

Organism Type: Mussel
Overall Risk Assessment Category: High

Photo: Boltovskoy. Licensed under CC BY-SA 4.0. Available: https://commons.wikimedia.org/wiki/File:Limnoperna_fortunei.jpg (March 2020).

1 Native Range and Status in the United States

Native Range

There is some confusion regarding the native range of *Limnoperna fortunei*. CABI (2020) states that *L. fortunei* is "native to Chinese and south-eastern Asian rivers and creeks". Bogan (2012) lists China (Guangxi, Hunan, Jiangsu, Guangdong), Thailand, and Viet Nam as native countries. Boltovskoy et al. (2009) considers *L. fortunei* as native to China, Thailand, Korea, Laos, Cambodia, Vietnam, and Indonesia. According to Bogan (2012), Magara et al. (2001) considers the species only native to China and introduced to all other countries. Further range details are

provided in the Native and Introduced sections of this ERSS, treating *L. fortunei* as native to China and Southeast Asia (Lao People's Democratic Republic, Thailand, Vietnam, Indonesia, and Cambodia).

From CABI (2020):

"*L. fortunei* is a freshwater mytilid of South East Asia; native to China, and also found [naturally] in Lao People's Democratic Republic, Cambodia, Vietnam, Indonesia and Thailand (Oliveira et al., 2006), typically found in freshwater systems; both rivers and lakes."

From Bogan (2012):

"Morton and Dinesen (2010) list the distribution of the species in China as: Yangtze basin - the lakes Dongting (Hunan Province), Yuangkian (Jiangsu Province), Chow-Wen-Miao, Chiang-Kia-Tsui, Jiangyin ('Siangyin'; Jiangsu Province) and Yoyang and adjacent rivers, and the Xiang River, near Changsha, Hunan Province). Also present in Thailand (Kwai River, Batambang, the mouth of the Kompong-Som River, the Mekong south of Nakon Ponom, the Maenam Mun River, the Lam Chi River, the Chao Phraya and Pasak rivers, the Tapi River, Tale Luang near Pattalung, Mekong branch at Muang Sene, Khong Island."

"Brandt (1974) listed it [in Thailand] from Mekong River south of Nakon Panom, Maenam Mun River, Lam Chi River, Chao Phraya and the Pasak River. In many klongs and tributaries to the Chao Phraya River, in the Maeklong River, in the south it reaches the Tapi River and Tale Luang near Pattalung."

Status in the United States

No records of *Limnoperna fortunei* in the wild or in trade in the United States were found.

From Fusaro et al. (2017):

"Ohio lists *L. fortunei* as an injurious aquatic invasive species and therefore it is unlawful for any person to possess, import, or sell live individuals within the state. Dead golden mussels can only be possessed in Ohio if they are preserved in ethanol or formaldehyde, or eviscerated (internal organs removed) (OH ADM. Code, 1501:31-18-01). In Michigan, it is illegal to possess, import, sell, or offer to sell *L. fortunei* (NREPA Part 413 as amended, MCL 324.41302). Illinois lists *L. fortunei* as an injurious species as defined by 50 CFR 16.11-15. Therefore, *L. fortunei* cannot be possessed, propagated, bought, sold, bartered or offered to be bought, sold, bartered, transported, traded, transferred or loaned to any other person or institution unless a permit is first obtained from the Department of Natural Resources. Illinois also prohibits the release of any injurious species, including *L.fortunei* (17 ILL. ADM. CODE, Chapter 1, Sec. 805). It is prohibited to transport, possess, or introduce *L. fortunei* in Wisconsin (Wisconsin Chapter NR 40). There are no regulations on L. fortunei in Minnesota, Indiana, Pennsylvania, or New York."

Means of Introductions in the United States

No records of *Limnoperna fortunei* in the wild in the United States were found.

Remarks

This ERSS was previously published in July 2014. Revisions were completed to incorporate new information and conform to updated standards.

According to the NIES (2020), *Limnoperna fortunei* is in the top 100 of Japan's worst invasive alien species.

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From MolluscaBase (2020):

"Animalia (Kingdom) > Mollusca (Phylum) > Bivalvia (Class) > Autobranchia (Subclass) > Pteriomorphia (Infraclass) > Mytilida (Order) > Mytiloidea (Superfamily) > Mytilidae (Family) > Arcuatulinae (Subfamily) > *Limnoperna* (Genus) > *Limnoperna fortunei* (Species)"

According to MolluscaBase (2020), the current taxonomic status of *Limnoperna fortunei* is accepted.

Size, Weight, and Age Range

From GISD (2017):

"Trocophore is the first planktonic stage (hours). Several stages of free-swimming planktonic veliger (D-larvae about 7 days, between 80-146 um; veliconcha between 90-237 um and pediveliger or umbonate, more than 256 um). Then the larvae settle as plantigrade mussels, attach to substrate as juveniles. Maturity is reached at about 5.5mm in length. Golden mussels live about 3.2 years."

From Fusaro et al. (2017):

"20-30 mm, max 42-46 mm"

Environment

From CABI (2020):

"*L. fortunei* inhabits rivers, streams, lakes, dams and estuaries. In Asia, it is found between 8-32°C, with confirmed occurrences up to 35°C. In South America, in a temperate area, *Limnoperna* populations can develop between 11 and 28ºC (approximately) (Darrigran et al., 2003). In a subtropical area, the reported temperatures are 17-29ºC (Mansur et al., 2004). It is intolerant to extended anaerobic conditions. Mansur et al. (2004) reported the pH tolerance range of 5.8-9.3. *L. fortunei* is a freshwater species that can inhabit brackish waters and maintain substantial populations in estuarine habitats. It is tolerant to polluted and contaminated waters with low calcium and pH levels."

From Oliveira et al. (2006):

“In the Paraguay River, the population density of *L. fortunei* can be negatively impacted by periodic low levels of dissolved oxygen and decreases in pH to between 5 and 6. Such conditions are frequently present during the periodic flooding or inundation of this area. Under these conditions, a high mortality of *L. fortunei* was recorded in March of 2002, on both natural and artificial substrates.”

Climate

According to CABI (2020), *Limnoperna fortunei* tolerates tropical wet and dry savanna climates (<60mm precipitation driest winter month and <(100 – [total annual precipitation{mm}/25])) and prefers warm temperate climates with dry winters (warm average temp. >10˚C, cold average temp. >0˚C). The mean annual air temperature range for *L. fortunei* is 8–33˚C.

Distribution Outside the United States

Native

There is some confusion regarding the native range of *Limnoperna fortunei*. CABI (2019) states that *L. fortunei* is “native to Chinese and south-eastern Asian rivers and creeks”. Bogan (2012) lists China (Guangxi, Hunan, Jiangsu, Guangdong), Thailand, and Viet Nam as native countries. Boltovskoy et al. (2009) considers *L. fortunei* as native to China, Thailand, Korea, Laos, Cambodia, Vietnam, and Indonesia. According to Bogan (2012), Magara et al. (2001) considers the species only native to China and introduced to all other countries. Further range details are provided in the Native and Introduced sections of this ERSS, treating *L. fortunei* as native to China and Southeast Asia (Lao People’s Democratic Republic, Thailand, Vietnam, Indonesia, and Cambodia).

From CABI (2020):

"*L. fortunei* is a freshwater mytilid of South East Asia; native to China, and also found [naturally] in Lao People’s Democratic Republic, Cambodia, Vietnam, Indonesia and Thailand (Oliveira et al., 2006), typically found in freshwater systems; both rivers and lakes."

From Bogan (2012):

“Morton and Dinesen (2010) list the distribution of the species in China as: Yangtze basin - the lakes Dongting (Hunan Province), Yuangkian (Jiangsu Province), Chow-Wen-Miao, Chiang-Kia-Tsui, Jiangyin ('Siangyin'; Jiangsu Province) and Yoyang and adjacent rivers, and the Xiang River, near Changsha, Hunan Province). Also present in Thailand (Kwai River, Batambang, the mouth of the Kompong-Som River, the Mekong south of Nakon Ponom, the Maenam Mun River, the Lam Chi River, the Chao Phraya and Pasak rivers, the Tapi River, Tale Luang near Pattalung, Mekong branch at Muang Sene, Khong Island. Recorded from Lao PDR [Lao People’s Democratic Republic] from the Kaek River, Huai San and Huai Koa Man in Loei Province, and from Cambodia (Lake Tonli Sap), Viet Nam (Lake Vin-Long, Mekong, Rham-Pehn, Cochinchine, Tonkin), Lao PDR in the Mekong drainage.”

"Brandt (1974) listed it [in Thailand] from Mekong River south of Nakon Panom, Maenam Mun River, Lam Chi River, Chao Phraya and the Pasak River. In many klongs and tributaries to the Chao Phraya River, in the Maeklong River, in the south it reaches the Tapi River and Tale Luang near Pattalung."

Introduced

According to Bogan (2012), *Limnoperna fortunei* has been introduced to Argentina, Bolivia; Plurinational States of, Brazil (Mato Grosso du Sul, Mato Grosso), Japan, Paraguay. *L. fortunei* is extant with uncertain origins in Taiwan, Democratic People's Republic of Korea, and Republic of Korea.

According to GISD (2017), *L. fortunei* has been introduced and established in the following South American countries with specific locations in parentheses: Argentina (Buenos Aires, Chaco, Corrientes, Distrito Federal, Entre Rios, Formosa, Misiones, Santa Fe), Brazil (Mato Grosso do Sul, Parana, Rio Grande do Sul), Paraguay (Alto Paraguay, Alto Parana, Central, Concepcion, Itapua, Misiones, Neembucu, Presidente Hayes, San Pedro), and Uruguay (Canelones, Colonia, Durazno, Montevideo, Rio Negro, Salto, San Jose, Soriano).

From NIES (2020):

"[Range in Japan] Tonegawa River System (Chiba and Ibaraki Prefs.), Lake Oshio (Gumma Pref.), Tenryu River (Shizuoka Pref.), Uregawa River (Aichi Pref.), Kisogawa River System (Gifu and Aichi Prefs.), and Lake Biwa-Yodogawa River System (Shiga, Kyoto, and Osaka Prefs.)."

Means of Introduction Outside the United States

From CABI (2020):

"Morton (1975) first recorded it in Hong Kong where it had been introduced from China via supplied potable water."

"*L. fortunei* has been accidentally introduced in South America. Darrigran and Pastorino (1995) proposed the non-intentional introduction of *L. fortunei* into the Río de la Plata in 1991, through ballast water of ocean vessels. At that time an increase of trade between Argentina and two countries that *L. fortunei* inhabits occurred. In Guaíba Basin, it was also probably introduced via ballast water (Mansur et al., 1999) and in the Itaipu reservoir (Zanella and Marenda, 2002) probably via boats used for sport."

"In South America, the identified vectors are commercial and sport ships and boats, live bait, nets, and buoys that spread the species through the basin. Other vectors are the trucks that transport sand from an invaded beach to other areas (Darrigran, 2002; Belz, 2006)."

"Magara et al. (2001) proposed that *L. fortunei* arrived in Japan before 1987 possibly with the Asian clam imported as food from mainland China."

From Boltovskoy et al. (2006):

"Along the Paraná-Paraguay waterway, which hosts intense boat traffic, *L. fortunei* has moved upstream at an average rate of of 250 km per year. In contrast, along the Uruguay river, where boat traffic is restricted to the lowermost 200 km section, upstream colonization is almost 10-times slower. This suggests that attachment to vessels is by far the most important dispersion mechanism."

Short Description

From CABI (2020):

"The shells of adult *L. fortunei* are equivalve and heteromyarian. It is dark-brown above the umbonal keel and paler yellow-brown below. This is caused by the nacre of the interior of the shell being purple above and white below the keel. The presence of a nacreous layer in *L. fortunei* removes this genus from all contact with Dreissenacea."

"The outer periostracal layer of the shell is smooth and shiny, and thick where it curls inwards at the shell margin. The umbones are very nearly terminal and the dorsal ligamental margin is straight or, at most, only slightly curved. The ventral margin of the shell is the most variable feature and in different specimens varied between the two extremes of being either straight or distinctly arcuate. There are no hinge teeth or byssal notches."

"The shells are yellow-brown. In clear water, for example in northern Argentina, they look golden; so it is called the 'golden mussel'."

Biology

From CABI (2020):

"Its [*Limnoperna fortunei*] longevity is variable. In the natural environment of Bagliardi Beach, Argentina, longevity was recorded as 3.2 years (Maroñas et al., 2003). Boltovskoy and Cataldo (1999) estimated it as 3 years in Cuenca del Plata, Argentina. Iwasaki and Uryu (1998) suggested a longevity of 2 years in the Uji River, Japan, from 4 to 5 years in Korea and over 10 years in central China."

"It is dioecious and reaches sexual maturity in the first year of its life span. Spawning occurs at temperatures of 16-28°C. After spawning and fertilization, the trocophore is the first planktonic stage. Several stages of free-swimming planktonic veliger (D-larvae about 7 days, between 80 and 146 mm; veliconcha between 90 and 237 mm and pediveliger or umbonate, more than 256 mm). Then the larvae settle as plantigrade mussels and attach to the substrate as juveniles. These larvae are free-swimming and planktonic and live in the water column. These stages of the mussel's life cycle are the most vulnerable to environmental fluctuations."

"The larvae settle to the bottom and securely attach to a hard substrate by byssal threads, which are secreted from a gland at the base of the mussel's muscular foot."

"*L. fortunei* are epifaunal, unlike most other South American native freshwater bivalves, and not overly selective, therefore they colonize almost any solid, submerged surface such as buoys, water intake pipes, rocks, rooted aquatic plants, boat hulls, and the shells of other molluscs. Its eurioic status allows a quick and effective distribution in water bodies. The juveniles differentiate into males and females; with lengths of 5 mm in the spring and 9 mm in the summer, and can reach sexual maturity after 6 mm total length (Darrigran et al., 2003)."

Human Uses

From GISD (2017):

"No uses are known for this species in its native area."

From CABI (2020):

"No productive benefit (economic, social or environmental) is known for *L. fortunei* invasion (Darrigran, 2002)."

From Fusaro et al. (2017):

"It is illegal to import, possess, deposit, release, transport, breed/grow, buy, sell, lease or trade [*Limnoperna*] *fortunei* in Ontario (Invasive Species Act 2015)."

From NIES (2020):

"Import, transport and keeping of genus *Limnoperna* are prohibited in Japan by the Invasive Alien Species Act."

Diseases

No records of OIE-reportable diseases (OIE 2020) were found for *Limnoperna fortunei*.

From CABI (2020):

"Associations between *L. fortunei* and other species have not been described. In South America, there are no records of *L. fortunei* as a vector of symbiotic organisms (commensals or parasites)."

According to MolluscaBase (2020), *Limnoperna fortunei* is a host of the endoparasite *Parabucephalopsis parasiluri*.

Threat to Humans

From CABI (2020):

"This kind of problem (freshwater macrofouling) is caused by the appearance of larvae or juveniles of *L. fortunei*. It impacts the sources of water supply of many water-treatment plants, industrial refrigeration systems, and power stations. Among the usual problems involved, the

following are the most significant: pipe obstruction; reduction in flow velocity in pipes due to friction loss (turbulent flows); accumulation of empty valves and pollution of water ways by massive mortality; filter occlusion; and increase in the corrosion of surfaces due to mussel infestation. This new economical and environmental problem for the neotropical regions produces unexpected expenses, for example, due to system shutdowns, the need for chemical or mechanical cleaning, and pipe and filter replacement."

3 Impacts of Introductions

In Japan, *Limnoperna fortunei* is considered one of the 100 worst invasive species and the import, transport, and keeping of *L. fortunei* is prohibited (NIES 2020). Ontario, Canada prohibits the import, possession, deposit, release, transport, breeding, buying, selling, lease or trade of *L. fortunei* (Fusaro et al. 2017). *L. fortunei* is regulated in multiple States.

From Fusaro et al. (2017):

"Ohio lists *L. fortunei* as an injurious aquatic invasive species and therefore it is unlawful for any person to possess, import, or sell live individuals within the state. Dead golden mussels can only be possessed in Ohio if they are preserved in ethanol or formaldehyde, or eviscerated (internal organs removed) (OH ADM. Code, 1501:31-18-01). In Michigan, it is illegal to possess, import, sell, or offer to sell *L. fortunei* (NREPA Part 413 as amended, MCL 324.41302). Illinois lists *L. fortunei* as an injurious species as defined by 50 CFR 16.11-15. Therefore, *L. fortunei* cannot be possessed, propagated, bought, sold, bartered or offered to be bought, sold, bartered, transported, traded, transferred or loaned to any other person or institution unless a permit is first obtained from the Department of Natural Resources. Illinois also prohibits the release of any injurious species, including *L. fortunei* (17 ILL. ADM. CODE, Chapter 1, Sec. 805). It is prohibited to transport, possess, or introduce *L. fortunei* in Wisconsin (Wisconsin Chapter NR 40). There are no regulations on *L. fortunei* in Minnesota, Indiana, Pennsylvania, or New York."

The following details documented, ***actual*** impacts of introduction for *L. fortunei*

From GISD (2017):

"The introduction of the golden mussel produces a rapid change in benthic communities and threatens native biodiversity. Golden mussels settle in high numbers on native bivalves (Hyriidae and Mycetopodidae), causing suffocation and starvation, leading to death. Since its invasion of the Plata Basin [South America], dense colonization of hard substrates has modified the presence and abundance of several species of native macroinvertebrates, homogenized the habitat and altered the diet of fish. One fish species (*Leporinus obtusidens* Valenciennes, 1846) has changed its diet to predate entirely on the golden mussel but is not a limiting factor for its dispersion. The golden mussel produces macrofouling in the water systems of facilities."

From CABI (2020):

"Freshwater macrofouling is a new economic/environmental problem for South America. Until the beginning of the 1990s, macrofouling in the neotropical region occurred only in marine and mixohaline waters. Since the introduction of *L. fortunei,* macrofouling also extended to

freshwaters in Argentina, Brazil, Paraguay and Uruguay (Darrigran and Damborenea, 2005). This kind of problem (freshwater macrofouling) is caused by the appearance of larvae or juveniles of *L. fortunei*. It impacts the sources of water supply of many water-treatment plants, industrial refrigeration systems, and power stations. Among the usual problems involved, the following are the most significant: pipe obstruction; reduction in flow velocity in pipes due to friction loss (turbulent flows); accumulation of empty valves and pollution of water ways by massive mortality; filter occlusion; and increase in the corrosion of surfaces due to mussel infestation. This new economical and environmental problem for the neotropical regions produces unexpected expenses, for example, due to system shutdowns, the need for chemical or mechanical cleaning, and pipe and filter replacement."

"The large biomass associated with high densities of *L. fortunei* impacts on aquatic food chains. Several species of native fish consume *L. fortunei* (López Armengol and Casciotta, 1998; Montalto et al., 1999) and it has become the main food source for *Leporinus obtusidens* (Anostomidea) in the Río de la Plata (Penchaszadeh et al., 2000)."

"The impact caused by *L. fortunei* it is not restricted to the economic aspect. Darrigran et al. (1998) showed that since the introduction of *L. fortunei* at Bagliardi Beach, two gastropods commonly found have been displaced: one of them, *Chilina fluminea*, is no longer found; whereas the other, *Gundlachia concentrica*, is becoming rare. In contrast, several benthic species, uncommon or absent before the occurrence of *L. fortunei* in this microenvironment, are now present, including the Annelids: Oligochaeta (eight species), Aphanoneura (one species) and Hirudinea (eight species). In addition, several species of crustaceans and insects never cited at the invaded areas are now present (Darrigran et al., 1998)."

"The most direct and severe ecological impact has been the epizoic colonization of native naiads (Hyriidae and Mycetopodidae) by *L. fortunei,* similar to the impact of *D. polymorpha* on native bivalves in North America (Ricciardi et al., 1997).The displacement of the native naiads resulted from their inability to open and shut their valves because of the byssally-attached mussels on their shells. The quantitative impact of *L. fortunei* on native naiads in South America is unknown. *L. fortunei* also settles on other native fauna, such as *Pomacea canaliculate* (Gastropoda, Ampullariidae) and *Aegla platensis* (Anomura, Aeglidae), as well as on the introduced *Corbicula fluminea* (Bivalvia, Corbiculidae) (Darrigran et al., 2000; Darrigran, 2002)."

From Oliveira et al. (2006):

"Despite low densities, *L. fortunei* can colonize water cooling systems of boats, obstructing water circulation and causing motor overheating. Accumulation in water supply equipment, such as pumps and pipes has also been observed."

From Boltovskoy et al. (2009):

"On the basis of diver-collected bottom samples, we estimated the overall density of this mussel in a reservoir (Embalse de Río Tercero, Argentina), where *Limnoperna* is present since 1998 and analyzed changes in several water-column properties before and after the invasion. The 47 km^2

reservoir hosts around 45 billion mussels; at these densities, a volume equivalent to that of this water body can potentially be filtered by the bivalves every 2–3 days. Data collected regularly since 1996 indicate that after the invasion water transparency increased, and suspended matter, chlorophyll *a*, and primary production decreased significantly, with strong changes occurring in the area with highest mussel densities. Our results indicate that the ecosystem-wide impacts of *Limnoperna* are generally comparable to those described in Europe and North America for another invasive mussel—*Dreissena polymorpha*."

From Boltovskoy et al. (2015):

"*Limnoperna* modifies nutrient concentrations and decreases concentrations of particulate organic matter in the water column (including phytoplankton and zooplankton), thus enhancing light penetration and stimulating growth of periphyton and macrophytes. Selective grazing and modification of the N:P ratio are responsible for strong enhancements of toxic cyanobacterial blooms. *Limnoperna* beds significantly enhance the numbers, biomass, and diversity of practically all accompanying invertebrates. The mussel's planktonic larvae represent an important food item for the larvae of 18 fish species, while juveniles and adults are consumed by at least 50 fish species. *Limnoperna* is the first and only abundant benthic filter-feeding animal in South American continental waters."

The following details theorized, ***potential*** impacts of introduction for *L. fortunei.*

From CABI (2020):

"However, many other aspects of the biology of *L. fortunei* are poorly understood (Sylvester et al., 2005), including its filtering capacity. Because of its high density in the Plata basin, *L. fortunei* could increase water clarity in a manner similar to that caused by *Dreissena polymorpha* in North America (Darrigran and Damborenea, 2005)."

From Cataldo et al. (2012):

"In order to evaluate the effects of the golden mussel *Limnoperna fortunei* on phytoplankton density and composition and nutrient recycling we conducted a 24 h filtration experiment in Río Tercero Reservoir (Argentina) using four 400 L mesocosms, two of them stocked with 1700-1800 adult mussels each, and two controls (without mussels). Nutrient concentrations and phytoplankton composition and density were evaluated at 0, 3, 6, 12, and 24 h. Estimated filtration rates were 1.48-3.14 mL mg DW-1 h-1. Grazing pressure by the mussel was not associated with algal taxonomy or cell size. After 24 h, *L. fortunei* removed 84% of the particulate nitrogen, and 49% of the particulate phosphorus. Nutrient regeneration was very significant as well: ammonium was produced at a rate of 3 μM NH3g DW-1 h-1, whereas production of phosphates was 0.42 μM PO4g DW-1 h-1. It is concluded that the impact of *L. fortunei* on phytoplankton and nutrient cycling can be as significant as that reported for another invasive bivalve - the zebra mussel *Dreissena polymorpha* in Europe and North America, but the overall effect of this impact on the biota may differ strongly under different environmental settings."

From Boltovskoy et al. (2006):

"Observations of the negative impacts of *L. fortunei* include reports from southern Brazil and Japan. In the area of Guaíba lake (southern Brazil), Mansur et al. (2003) reported that the mussel attaches to at least 6 species of molluscs, including 2 unionids, in numbers of up to ca. 300 *L. fortunei* per host. In several cases this over growth may hinder the host's normal displacement and valve mobility. The same authors also suggested that *L. fortunei*'s settlements on the roots of the reed *Scirpus californicus*, an emergent helophyte, may be 'suffocating' the plants and be responsible for the thinning of reed populations. Howewer [sic], this effect is unlikely because the roots of *Scirpus* must be adapted to the very low oxygen environment characteristic of shallow areas with very abundant organic debris. Furthermore, filtering bivalves are known to enhance water oxygenation, rather than the opposite (e.g. Karatayev et al. 1997)."

"Another potential threat posed by this invader was reported by Ogawa et al. (2004). The authors identified widespread parasitic infections by bucephalid trematodes in several cyprinid fishes from the Uji river, suggesting that the infections started with the accidental introduction of infested first intermediate hosts – *Limnoperna fortunei*."

"Among the potentially positive impacts, enhancement of the diversity and abundance of most other benthic organisms (Darrigran et al. 1998), and consumption by fish have been mentioned. Trophic interactions with fish are of particular interest because the mussel represents a novel resource available at an unprecedented scale. At least 16 species have been recorded in the Paraná and Río de la Plata rivers that actively consume *L. fortunei* (Montalto et al. 1999; Ferriz et al. 2000; Penchaszadeh et al. 2000; Cataldo et al. 2002). Some of the commercially most valuable species, like *Pterodoras granulosus* and *Leporinus obtusidens*, have been observed to feed preferentially on *L. fortunei*: up to 100% of the specimens retrieved in the summer have their guts filled predominantly or exclusively with remains of this mollusc (Ferriz et al. 2000; Penchaszadeh et al. 2000; Cataldo et al. 2002)."

4 History of Invasiveness

Although *Limnoperna fortunei* has not been introduced to the United States, it has been introduced and become established in a number of other countries outside of its native range. Impacts of these introductions have been well documented. *L. fortunei* has been shown to displace and alter diets of other organisms. *L. fortunei* has also been reported to have impacts similar to that of the zebra mussel, *Dreissena polymorpha*, causing macrofouling and water clarity alterations. These impacts are documented by reputable sources. The history of invasiveness for *Limnoperna fortunei* is classified as High.

5 Global Distribution

Figure 1. Known global distribution of *Limnoperna fortunei*. Observations are reported from China, Japan, Thailand, Vietnam, Cambodia, Lao People's Democratic Republic, Brazil, Uruguay, and Argentina. Map from GBIF Secretariat (2020).

Populations of *L. fortunei* are also reported from Democratic People's Republic of Korea, Republic of Korea, Indonesia, Taiwan, Indonesia, Bolivia and Paraguay (Bogan 2012, GISD 2017, Fusaro et al. 2017) but no geospatial data was found in the literature search.

6 Distribution Within the United States

No records of *Limnoperna fortunei* in the wild in the United States were found.

7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Limnoperna fortunei* was high throughout the east, southeast, and central area of the contiguous United States. The west and most of the northern area of the country was low. The overall Climate 6 score (Sanders et al. 2018; 16 climate variables; Euclidean distance) for the contiguous United States was 0.184, high (scores of 0.103 and greater are classified as high). The following States had high individual Climate 6 scores: Alabama, Arkansas, Delaware, Florida, Georgia, Illinois, Indiana, Louisiana, Maryland, Missouri, Mississippi, North Carolina, New Jersey, New Mexico, Ohio, Oklahoma, Pennsylvania, South Carolina, Texas, Virginia, and West Virginia. States with medium individual climate scores included Arizona, Kentucky, Michigan, New York, and Tennessee. All other States had low individual climate scores.

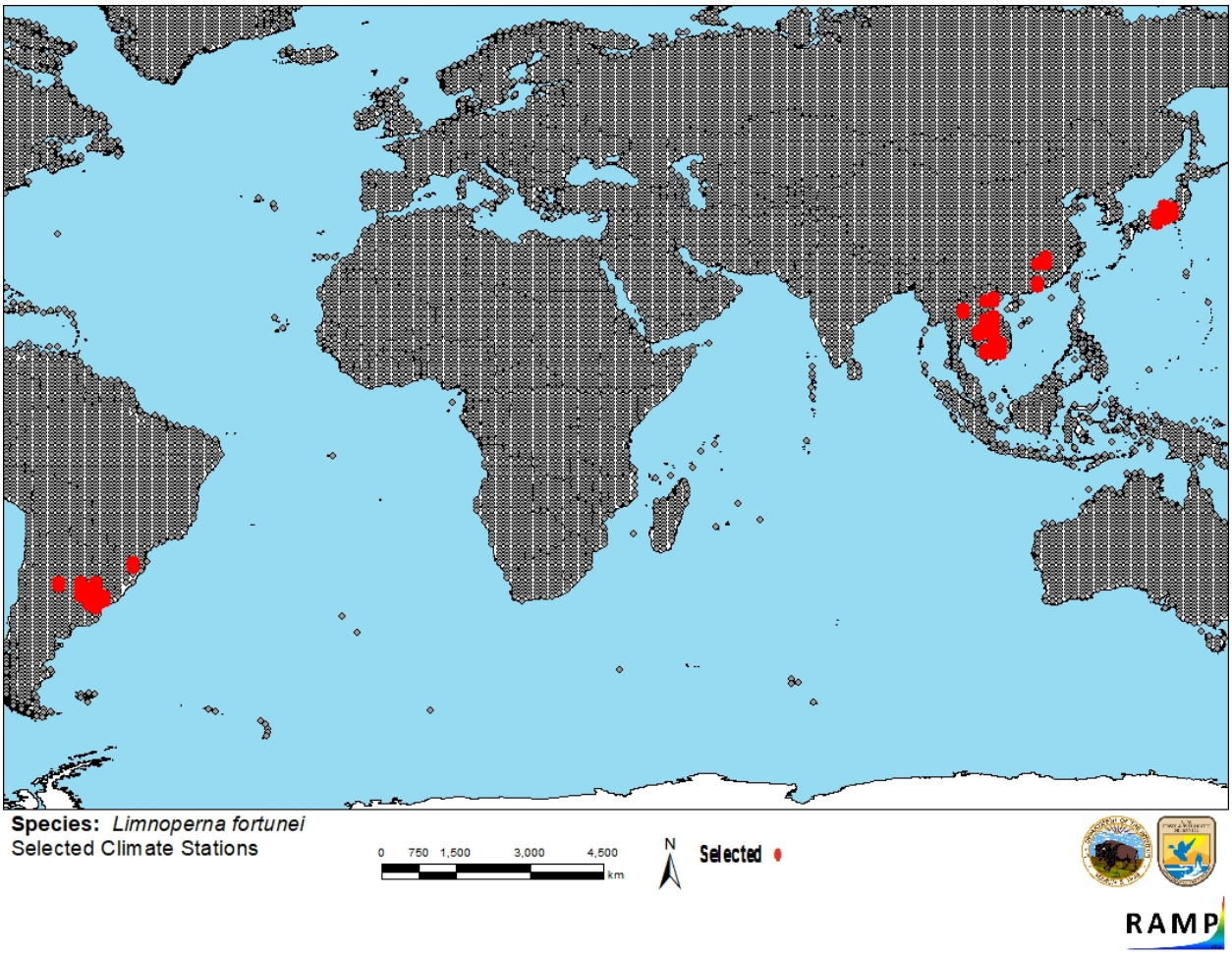

Figure 2. RAMP (Sanders et al. 2018) source map showing weather stations in China, Japan, Thailand, Vietnam, Cambodia, Lao People's Democratic Republic, Brazil, Uruguay, and Argentina selected as source locations (red) and non-source locations (gray) for *Limnoperna fortunei* climate matching. Source locations from GBIF Secretariat (2020). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

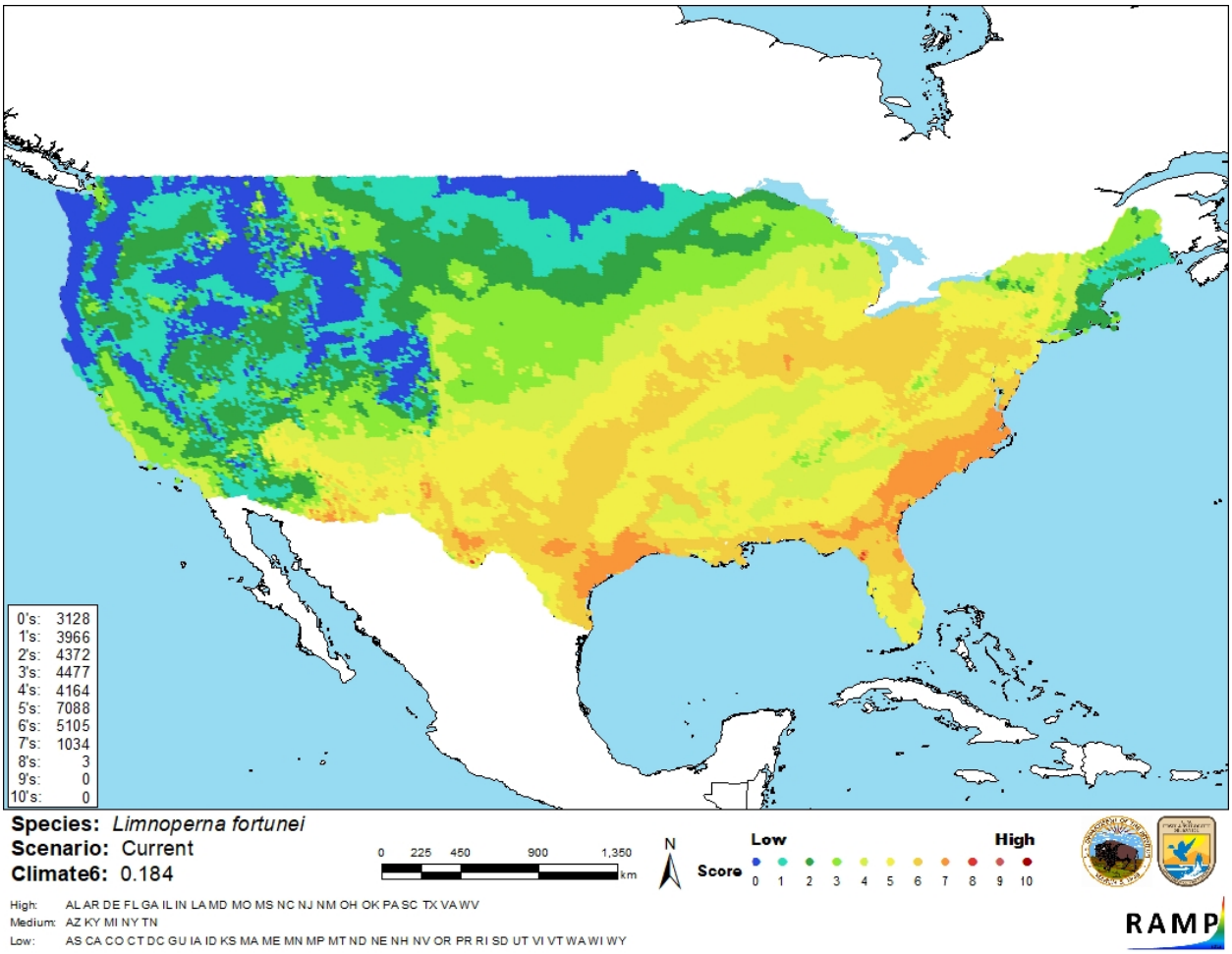

Figure 3. Map of RAMP (Sanders et al. 2018) climate matches for *Limnoperna fortunei* in the contiguous United States based on source locations reported by GBIF Secretariat (2020). Counts of climate match scores are tabulated on the left. 0/Blue = Lowest match, 10/Red = Highest match.

The High, Medium, and Low Climate match Categories are based on the following table:

Climate 6: (Count of target points with climate scores 6-10)/ (Count of all target points)	Overall Climate Match Category
0.000≤X≤0.005	Low
0.005<X<0.103	Medium
≥0.103	High

8 Certainty of Assessment

Information regarding the distribution and invasiveness of *Limnoperna fortunei* is readily available. The available data from peer-reviewed sources show mostly negative impacts where the species has been introduced. Populations of *L. fortunei* are reported from Democratic People's Republic of Korea, Republic of Korea, Indonesia, Taiwan, Indonesia, Bolivia and Paraguay but no geospatial data was found in the literature search, the absence of these countries in the climate match may reduce the certainty. The certainty of this assessment is high.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Limnoperna fortunei, the golden mussel, is a mussel native to China and possibly some of Southeast Asia as there is some confusion around the species native range. It has been introduced to a number of other countries where it has become established. Negative impacts, such as macrofouling, water clarity alteration, displacement and diet alteration of other species have been reported from these areas. Regulations for this species exist in Japan, Ontario (Canada), Ohio, Michigan, Illinois, and Wisconsin. *L. fortunei* has not been introduced to the United States but a number of sources report it as likely, comparing it to *Dreissena polymorpha*, due to its environmental tolerance and invasiveness. The history of invasiveness for *L. fortunei* is classified as High. The overall climate match was high, with the central, east, and southeast areas of the contiguous United States having high matches. The overall risk assessment category for *Limnoperna fortunei* is high.

Assessment Elements

- **History of Invasiveness (Sec. 4): High**
- **Overall Climate Match Category (Sec. 7): High**
- **Certainty of Assessment (Sec. 8): High**
- **Remarks/Important additional information:** No additional information.
- **Overall Risk Assessment Category: High**

10 Literature Cited

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 11.

Bogan A. 2012. *Limnoperna fortunei*. The IUCN Red List of Threatened Species 2012. e.T171818A1332873. Available: https://www.iucnredlist.org/species/171818/1332873 (March 2020).

Boltovskoy D, Correa N. 2015. Ecosystem impacts of the invasive bivalve *Limnoperna fortunei* (golden mussel) in South America. Hydrobiologia 746:81–95.

Boltovskoy D, Correa N, Cataldo D, Sylvester F. 2006. Dispersion and ecological impact of the invasive freshwater bivalve *Limnoperna fortunei* in the Río de la Plata watershed and beyond. Biological Invasions 8:947–963.

Boltovskoy D, Karatayev A, Burlakova L, Cataldo D, Karatayev V, Sylvester F, Mariñelarena A. 2009. Significant ecosystem-wide effects of the swiftly spreading invasive freshwater bivalve *Limnoperna fortunei*. Hydrobiologia 636:271–284.

[CABI] CAB International. 2020. *Limnoperna fortunei* (golden mussel). CABI Invasive Species Compendium. Wallingford, United Kingdom: CAB International. Available: https://www.cabi.org/isc/datasheet/107775 (March 2020).

Cataldo D, Farrell IO, Paolucci E, Sylvester F, Boltovskoy D. 2012. Impact of the invasive golden mussel (*Limnoperna fortunei*) on phytoplankton and nutrient cycling. Aquatic Invasions 7:91–100.

Fusaro A, Davidson A, Alame K, Gappy M, Baker E, Nunez G, Larson J, Conard W, Alsip P. 2017. *Limnoperna fortunei*. Gainesville, Florida: U.S. Geological Survey, Nonindigenous Aquatic Species Database. Available: https://nas.er.usgs.gov/queries/greatlakes/FactSheet.aspx?SpeciesID=68&Potential=Y&Type=2&HUCNumber= (April 2020).

GBIF Secretariat. 2020. GBIF backbone taxonomy: *Limnoperna fortunei* (Dunker, 1857). Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/5855350 (March 2020).

[GISD] Global Invasive Species Database. 2017. Species profile: *Limnoperna fortunei*. Gland, Switzerland: Invasive Species Specialist Group. Available: http://www.iucngisd.org/gisd/speciesname/Limnoperna+fortunei (March 2020).

MolluscaBase. 2020. *Limnoperna fortunei* (Dunker, 1857). World Register of Marine Species. Available: http://www.marinespecies.org/aphia.php?p=taxdetails&id=506081#attributes (March 2020).

[NIES] National Institute for Environmental Studies. 2020. *Limnoperna fortunei*. Invasive species of Japan. Tsukuba, Japan: National Research and Development Agency, National Institute for Environmental Studies. Available: https://www.nies.go.jp/biodiversity/invasive/DB/detail/70200e.html (March 2020).

[OIE] World Organisation for Animal Health. 2020. OIE-listed diseases, infections and infestations in force in 2020. Available: http://www.oie.int/animal-health-in-the-world/oie-listed-diseases-2020/ (January 2020).

Oliveira MD, Takeda AM, Barros LF, Barbosa DS, Resende EK. 2006. Invasion by *Limnoperna fortunei* (Dunker, 1857) (Bivalvia, Mytilidae) of the Pantanal wetland, Brazil. Biological Invasions 8:97–104.

Sanders S, Castiglione C, Hoff M. 2018. Risk Assessment Mapping Program: RAMP. Version 3.1. U.S. Fish and Wildlife Service.

11 Literature Cited in Quoted Material

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.

Belz CE. 2006. Análise de risco de bioinvasão por *Limnoperna fortunei* (Dunker, 1857): um modelo para a bacia do rio Iguaçu, Paraná. Brazil: Departamento de Zoologia da Universidade Federal do Paraná Brazil. (In Portuguese.)

Boltovskoy D, Cataldo D. 1999. Population dynamics of *Limnoperna fortunei*, an invasive fouling mollusc, in the Lower Paraná River (Argentina). Biofouling 14(3):255–263.

Brandt RAM. 1974. The non-marine aquatic Mollusca of Thailand. Archiv für Molluskenkunde 105(1–4):1–423.

Cataldo D, Boltovskoy D, Marini V, Correa N. 2002. Limitantes de la expansión de *Limnoperna fortunei* en la cuenca del Plata: la predación por peces. Paysandú, Uruguay: Terceras Jornadas sobre la Conservacioń de la Fauna Ictica del Río Uruguay 25–26 April 2002. (In Spanish.)

Darrigran G. 2002. Potential impact of filter feeding invaders on temperate inland freshwater environments. Biological Invasions 4:145–156.

Darrigran G, Damborenea C. 2005. A South American bioinvasion case history: *Limnoperna fortunei* (Dunker, 1857), the golden mussel. American Malacological Bulletin 20:105–112.

Darrigran G, Damborenea C, Penchaszadeh P, Taraborelli C. 2003. Adjustment of *Limnoperna fortunei* (bivalvia: mytilidae) after ten years of invasion in the Americas. Journal of Shellfish Research 22:141–146.

Darrigran G, Martin SM, Gullo B, Armendáriz L. 1998. Macroinvertebrados associated to the byssus of *Limnoperna fortunei* (Dunker, 1857) (Pelecipoda, Mytilidae). Río de la Plata, Argentina. Hydrobiologia 367:223–230. (In Spanish.)

Darrigran G, Penchaszadeh P, Damborenea C. 2000. An invasion tale: *Limnoperna fortunei* (Dunker, 1857) (Mytilidae) in the Neotropics. Pages 219–224 in Claudi R, editor. Proceedings of the 10th International Aquatic Nuisance Species and Zebra-Mussels Conference. Ontario, Canada: The Professional Edge Pembroke.

Darrigran G, Pastorino G. 1995. The recent introduction of Asiatic bivalve, *Limnoperna fortunei* (Mytilidae) in to South America. The Veliger 38(2):183–187.

Ferriz RA, Villar CA, Colautti D, Bonetto C. 2000. Alimentación de *Pterodoras granulosus* (Valenciennes) (Pisces, Doradidae) en la baja cuenca del Plata Revista del Museo Argentino de Ciencias Naturales 'Bernardino Rivadavia', Nueva Serie. Hydrobiologia 2:151–156. (In Spanish.)

Illinois Department of Natural Resources. 2015. Title 17: Conservation, Part 805 Injurious Species. United States. 17 Illinois Administrative Code, Chapter 1, Sec. 805.

[Invasive Species Act 2015] Downe J. 2015. Invasive Species Act, 2015. Peterborough, Ontario, Canada: Ministry of Natural Resources. Regulatory Act 16-MNRF010.

Iwasaki K, Uryu Y. 1998. Life cycle of a freshwater Mytilid mussel, *Limnoperna fortunei*, in Uji River, Kyoto. Venus 57:105–113.

Karatayev AY, Burlakova LE, Padilla DK. 1997. The effects of *Dreissena polymorpha* (Pallas) invasion on aquatic communities in Eastern Europe. Journal of Shellfish Research 16:187–203.

López-Armengol MF, Casciotta J. 1998. First record of the predation of the introduced freshwater bivalve *Limnoperna fortunei* (Mytilidae) by the native fish Micropogonias (Scianidae) in the Río de la Plata estuary, South America. Iberus 16(2):105–108.

Magara Y, Matsui Y, Goto Y, Yuasa A. 2001. Invasion of the non-indigenous nuisance mussel, *Limnoperna fortunei*, into water supply facilities in Japan. Journal of Water Supply: Research and Technology 50(3):113–124.

Mansur MC, Rossoni Cardoso F, Amato Ribeiro L, Pinheiro dos Santos C, Itidiero Thormann B, Costa da Fernández F, Zani Richinitti L. 2004. Distribuçao e concequencias após cinco anos da invasao do mexilhao-dourado, *Limnoperna fortunei* no estado do Rio Grande do Sul, Brasil (Mollusca, Bivalvia, Mytilidae). Biociencias 12:165–172. (In Portuguese.)

Mansur MCD, dos Santos CP, Darrigran G, Heydrich I, Callil CT, Cardoso FR. 2003. Primeiros dados quali-quantitativos do mexilhão-dourado, *Limnoperna fortunei* (Dunker), no Delta do Jacuí, no Lago Guaíba e na Laguna dos Patos, Rio Grande do Sul, Brasil e alguns aspectos de sua invasão no novo ambiente. Revista Brasileira de Zoologia 20: 75–84. (In Spanish.)

Mansur MCD, Zani Richinitti IM, Pinheiro dos Santos C. 1999. *Limnoperna fortunei* (Dunker, 1857), molusco bivalvo invasor, na Bacia do Guaiba, Rio Grande do Sul, Brasil. Biociencias 7:147–149. (In Portuguese.)

Maroñas M, Darrigran GA, Sendra E, Breckon G. 2003. Shell growth of the golden mussel, *Limnoperna fortunei* (Dunker, 1857) (Mytilidae), from a Neotropical temperate locality. Hydrobiologia 495:41–45.

Montalto LO, Oliveros B, Ezcurra de Drago I, Demonte LD. 1999. Peces del río Paraná medio predadores de una especie invasora: *Limnoperna fortunei* (Bivalvia, Mytilidae). Revista de la Facultad de la Facultad de Bioquímica y Ciencias Biológicas de la Universidad Nacional de Litoral 3:85–103. (In Spanish.)

Morton B. 1975. The colonisation of Hong Kong's raw water supply system by *Limnoperna fortunei* (Dunker 1857) (Bivalvia: Mytilacea) from China. Malacological Review 8:91–105.

Morton B, Dinesen GE. 2010. The biology and functional morphology of *Modiolarca subpicta* (Bivalvia: Mytilidae: Musculinae), epizoically symbiotic with *Ascidiella aspersa* (Urochordata: Ascidiacea), from the Kattegat, northern Jutland, Denmark. Journal of the Marine Biological Association of the United Kingdom91(8):1637–1649.

NREPA Part 413 as amended, MCL 324.41302. Michigan Department of Natural Resources. 2009. Invasive Species Order. United States. Ammendment MCL 324.41302.

OH ADM. Code, 1501:31-18-01. Ohio Department of Natural Resources. 2016. United States. Source material did not give full citation for this reference.

Ogawa K, Nakatsugawa T, Yasuzaki IM. 2004. Heavy metacercarial infections of cyprinid fishes in Uji River. Fisheries Science 70:132–140.

Oliveira MD, Hamilton SK, Jacobi CM. 2010. Forecasting the expansion of the invasive golden mussel *Limnoperna fortunei* in Brazilian and North American rivers based on its occurrence in the Paraguay River and Pantanal wetland of Brazil. Aquatic Invasions 5:59–73.

Oliveira MD de, Takeda AM, Barros LF de, Barbosa DS, Resende EK de. 2006. Invasion by *Limnoperna fortunei* (Dunker, 1857) (Bivalvia, Mytilidae) of the Pantanal wetland, Brazil. Biological Invasions 8:97–104.

Penchaszadeh PE, Darrigran G, Angulo C, Averbuj A, Brignoccoli N, Brogger M, Dogliotti A, Pirez N. 2000. Predation on the invasive freshwater mussel *Limnoperna fortunei* (Dunker, 1857) (Mytilidae) by the fish *Leporinus obtusidens* (Valenciennes, 1846) (Anostomidae) in the Río de la Plata, Argentina. Journal of Shellfish Research 19:229–231.

Ricciardi A, Whoriskey FG, Rasmussen JB. 1997. The role of the zebra mussel (*Dreissena polymorpha*) in structuring macroinvertebrate communities on hard substrata. Canadian Journal of Fisheries and Aquatic Sciences 54:2596–2608.

Sylvester F, Dorado J, Boltovskoy D, Juárez A, Cataldo D. 2005. Filtration rates of the invasive pest *Limnoperna fortunei* as a function of size and temperature. Hydrobiologia 534:71–80.

Wisconsin Chapter NR 40. Wisconsin Department of Natural Resources. 2017. Chapter NR 40 Invasive Species Identification, Classification, and Control. United States. Administrative Code NR 40.

Zanella O, Marenda LD. 2002. Ocorrência de *Limnoperna fortunei* na Central Hidroeléctrica de Itaipu. V Congreso Latinoamericano de Malacología. San Pablo, Brasil: Resúmenes 41. (In Portuguese.)