New Zealand Mudsnail (*Potamopyrgus antipodarum*)
Ecological Risk Screening Summary

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


Photo: USGS

1 Native Range, and Status in the United States

Native Range
From CABI (2015):

"*P. antipodarum* is native to New Zealand and adjacent islands (Ponder, 1988)."

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

"This snail was first discovered in the middle portion of the Snake River in Idaho in 1987. By 1995, the mudsnail had reached the Madison River in Montana and into Yellowstone National

Park the following year (Wyoming). It is also established in Minidoka National Wildlife Refuge, Idaho (USFWS 2005). Since then, they have been found in the Madison River and several other rivers in and near Yellowstone National Park. Populations were discovered near the mouth of the Columbia River in Oregon in 1997, and the Owens River in California. Since then, this species is becoming very widespread in California. This species became established in the lower Columbia River, Washington about 1999 (M. Sytsma, pers. comm.) and in the Colorado River in northern Arizona (M. Anderson, pers. comm.) by 2002. In Utah, the first mudsnails were found about 2001 and have since been found in the Green River and many others. In 2004, mudsnails were found in small Colorado creek near Boulder (P. Walker, pers. comm.)."

"Great Lakes - *P. antipodarum* was found established in Lake Ontario in 1991 (Zaranko et al. 1997) and in Lake Erie (Ohio and Pennsylvania) in 2005 (Levri et al. 2007). It may also be established in Duluth-Superior Harbor (Minnesota/Wisconsin) of Lake Superior, where some individuals were found in 2001 (Grigorovich et al. 2003). They have also been collected from southwestern Lake Ontario, New York, the Welland Canal and northeastern Lake Ontario, Ontario, Canada as well as Lake Superior at Thunder Bay, Ontario, Canada in 2001. A population was discovered in Lake Michigan, off Waukegan, Illinois in 2006 (T. Nalepa, pers.comm.)."

"This species is established in Lake Ontario, Lake Erie, Lake Michigan and most likely in Lake Superior and is expanding its range within the Great Lakes basin (Levri et al. 2007). In the Great Lakes, the snail reaches densities as high as 5,600 per square meter. (Levri et al. 2007, Zaranko et al. 1997). Also established in all western states where it is found in the US."

Means of Introductions in the United States

From Benson et al. (2015):

"*P. antipodarum* was most likely introduced to the Great Lakes in ships from Europe, where there are nonindigenous populations (Zaranko et al. 1997; Leppäkoski & Olenin 2000; Levri et al. 2007) or in the water of live gamefish shipped from infested waters to western rivers in the United States."

Remarks

From Benson et al. (2015):

"*Potamopyrgus antipodarum* is synonymous with *P. jenkinsi* and *Hydrobia jenkinsi*."

"Mudsnail populations consist mostly of asexually reproducing females that are born with developing embryos in their reproductive system. This species can be found in all types of aquatic habitats from eutrophic mud bottom ponds to clear rocky streams. It can tolerate a wide range of water temperatures (except freezing), salinity, and turbidity in clean as well as degraded waters. They feed on dead and dying plant and animal material, algae, and bacteria. Its tolerance of a broad range of ecological factors make the possibility of further spread likely. In moist conditions, this snail can withstand short periods of desiccation (Richards et al. 2004)."

"The public should be careful to decontaminate fishing and sporting equipment so as not to spread existing populations or start new ones. Regulations on commercial shipping of this species are in effect. The species supports a number of parasites in its native range, but none have been found on North American populations examined."

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

From ITIS (2015):

"Kingdom Animalia
  Subkingdom Bilateria
    Infrakingdom Protostomia
      Superphylum Lophozoa
        Phylum Mollusca
          Class Gastropoda
            Order Neotaenioglossa
              Family Hydrobiidae
                Genus Potamopyrgus
                  Species *Potamopyrgus antipodarum* (J. E. Gray, 1853)"

"Taxonomic Status: valid"

Size, Weight, and Age Range

From Benson et al. (2015):

"The snail is usually 4 to 6 mm in length in the Great Lakes, but grows to 12 mm in its native range (Levri et al. 2007, Zaranko et al. 1997)."

Environment

From CABI (2015):

"Within its native range *P. antipodarum* lives in freshwater ecosystems, except temporary ponds, as well as brackish waters (Winterbourn, 1973). However, in its non-native range, it can be found in either in freshwater, brackish and even salty water, and has been recorded in streams, rives, lakes, reservoirs, channels, isolated coastal lakes, shallow lakes, estuaries and open seas (Alonso and Castro-Díez, 2008; 2012a)."

Climate/Range

From Benson et al. (2015):

"It tolerates temperatures of 0–34°C (Cox and Rutherford 2000, Zaranko et al. 1997)."

Distribution Outside the United States

Native

From GISD (2011):

"New Zealand"

Introduced

From GISD (2011):

"Austria, Australia, Baltic Sea, Belgium, Black Sea, Canada, Channel Is. (UK), Czech Republic, Denmark, England, Estonia, Finland, France, Germany, Great Lakes (USA), Greece, Italy, Iraq, Japan, Latvia, Lebanon, Lithuania, Netherlands, Northern Ireland, Norway, Poland, Romania, Russian Federation, Scotland, Sea of Azov, Slovakia, Slovenia, Spain, St. Lawrence River, Sweden, Switzerland, Turkey, Ukraine"

Means of Introduction Outside the United States

From GISD (2011):

"**Introduction pathways to new locations**
Agriculture: Commercial movement of aquaculture products, such as live fish or eggs may be an important vector for *Potamopyrgus antipodarum* spread (Loo et al, 2007a).
Ignorant possession: The National Park Service [2003] states that "the rapid spread of P. antipodarum throughout the Madison River watershed may have been assisted by human transport. Mud snails are able to withstand desiccation, a variety of temperature regimes, and are small enough that many types of water users (anglers, swimmers, picnickers, pets) could inadvertently be the mechanism for interbasin transfer of this nuisance species."
Seafreight (container/bulk): JNCC (2002) states that *P. antipodarum* "was introduced in drinking water barrels in ships from Australia (Ponder 1988, in JNCC, 2002). The snails were probably liberated while washing or filling water barrels or tanks and, because they can survive in brackish water, they could probably survive liberation into estuarine areas such as the River Thames."
Ship ballast water: The most frequently cited method of long distance dispersal of *Potamopyrgus antipodarum* is through ship ballast water (Alonso & Castro-D[í]ez, 2008).
Ship/boat hull fouling:
Stocking: The introduction of *Potamopyrgus antipodarum* along with fish stocking may be method of its invasion of new locations (Hosea & Finlayson, 2005; Loo et al, 2007b)."

"**Local dispersal methods**
Boat:
Consumption/excretion: *Potamopyrgus antipodarum* is capable of surviving passage through digestion of birds and fish and may be dispersed by them (Cejka et al, 2008).
Hikers' clothes/boots: The National Park Service [2003] states that "the rapid spread of P. antipodarum throughout the Madison River watershed may have been assisted by human transport. Mud snails are able to withstand desiccation, a variety of temperature regimes, and are

small enough that many types of water users (anglers, swimmers, picnickers, pets) could inadvertently be the mechanism for interbasin transfer of this nuisance species."
On animals: *Potamopyrgus antipodarum* may be dispersed to new locations on birds or fish (Alonso & Castro-D[í]ez, 2008).
On clothing/footwear: *Potamopyrgus antipodarum* may be spread anthropogenically on waders, boots, or angling equipment (Davidson et al, 2008).
Water currents: *Potamopyrgus antipodarum* may be dispersed by water currents on floating macrophytes (Alonso & Castro-D[í]ez, 2008)."

Short description

From CABI (2015):

"*P. antipodarum* has a solid operculum (i.e. a cover in the shell aperture) (Alonso and Castro-Díez, 2008) and its shell colour ranges from light to dark brown. Both males and females are morphologically very similar, but females have developing embryos in their reproductive systems (Jokela et al., 1997). The surface of the shell is characterized by right-handed coiling of 5-6 whorls. Some individuals have spines in the middle of each shell whorl."

Biology

From Benson et al. (2015):

"*Potamopyrgus antipodarum* is a nocturnal grazer, feeding on plant and animal detritus, epiphytic and periphytic algae, sediments and diatoms (Broekhuizen et al. 2001, James et al. 2000, Kelly and Hawes 2005, Parkyn et al. 2005, Zaranko et al. 1997)."

"The snail tolerates siltation, thrives in disturbed watersheds, and benefits from high nutrient flows allowing for filamentous green algae growth. It occurs amongst macrophytes and prefers littoral zones in lakes or slow streams with silt and organic matter substrates, but tolerates high flow environments where it can burrow into the sediment (Collier et al. 1998, Death et al. 2003, Holomuzki and Biggs 1999, Holomuzki and Biggs 2000, Negovetic and Jokela 2000, Richards et al. 2001, Schreiber et al. 2003, Suren 2005, Weatherhead and James 2001, Zaranko et al. 1997)."

"*Potamopyrgus antipodarum* is ovoviviparous and parthenogenic. Native populations in New Zealand consist of diploid sexual and triploid parthenogenically cloned females, as well as sexually functional males (less than 5% of the total population). All introduced populations in North America are clonal, consisting of genetically identical females. The snail produces approximately 230 young per year. Reproduction occurs in spring and summer, and the life cycle is annual (Gerard et al. 2003, Hall et al. 2003, Lively and Jokela 2002, Schreiber et al. 1998, Zaranko et al. 1997). They are found in the Great Lakes at depths of 4-45 m on a silt and sand substrate (Levri et al. 2007, Zaranko et al. 1997)"

"This species is euryhaline, establishing populations in fresh and brackish water. The optimal salinity is probably near or below 5 ppt, but *P. antipodarum* is capable of feeding, growing, and reproducing at salinities of 0–15 ppt and can tolerate 30–35 ppt for short periods of time (Costil et al. 2001, Gerard et al. 2003, Jacobsen and Forbes 1997, Leppäkoski and Olenin 2000, Zaranko et al. 1997). It tolerates temperatures of 0–34°C (Cox and Rutherford 2000, Zaranko et al. 1997). *Potamopyrgus antipodarum* can survive passage through the guts of fish and may be transported by these animals (Bruce 2006). It can also float by itself or on mats of *Cladophora* spp., and move 60 m upstream in 3 months through positive rheotactic behavior (Zaranko et al. 1997). It can respond to chemical stimuli in the water, including the odor of predatory fish, which causes it to migrate to the undersides of rocks to avoid predation (Levri 1998). Common parasites of this snail include trematodes of the genus *Microphallus* (Dybdahl and Krist 2004)."

Human uses

From CABI (2015):

"There is no commercial interest in *P. antipodarum* as food nor as a pet"

"Research model"

Diseases

From Benson et al. (2015):

"Common parasites of this snail include trematodes of the genus *Microphallus* (Dybdahl and Krist 2004)."

From CABI (2015):

"The number of parasite species and their incidence on *P. antipodarum* populations in invaded ecosystems has been reported to be very low (Zbikowski and Zbikowska, 2009)."

Threat to humans

From GISD (2011):

"Direct as well as indirect impacts on fish by *P. antiopdarum* threaten fisheries in locations where it has established. Additionally, *P. antiopdarum* has fouling potential as it is known to pass through water pipes, emerge from domestic traps, and may block water pipes, meters, or irrigation systems (Ponder, 1988; Cotton, 1942 in Zaranko, 1997; NZMS Working Group, 2006). *P. antipodarum* has also been found to be infected by blood fluke *Sanguinicola sp.* in Europe and represents a possible vector to new locations (Gerard & LeLannic, 2003)."

3 Impacts of Introductions

From Benson et al. (2015):

"Abundant populations of introduced *P. antipodarum* may outcompete other grazers and inhibit colonization by other macroinvertebrates (Kerans et al. 2005). In Europe, *P. antipodarum* causes declines in species richness and abundance of native snails in constructed ponds (Strzelec 2005).

By contrast, in one Australian stream, increasing densities of *P. antipodarum* are positively correlated with density and species richness of native invertebrates, possibly due to coprophagy (ingestion of the snail's faeces) (Schreiber et al. 2002). In geothermal streams in the western U.S., *P. antipodarum* reaches densities of 300,000 snails m^2 and alters nutrient (nitrogen and carbon) flows, consumes large amounts of GPP, accounts for most of the invertebrate production (Hall et al. 2003)."

"It also may compete for food and space occupied by native snails. There is some evidence in their native range that trout may avoid these snails as a prey."

"It is suspected that they can alter primary production of streams and spread rapidly (USEPA 2008)."

From GISD (2011):

"*Potamopyrgus antipodarum* may establish very dense populations, consume large amounts of primary production, alter ecosystem dynamics, compete with and displace native invertebrates, and negatively influence higher trophic levels. Its ecological plasticity, high competitive ability, high reproductive rate, high capacity for various dispersal methods, and ability to avoid predation make it a formidable colonizer capable of establishing abundant populations with significant effects on ecosystems (Alonso & Castro-D[í]ez, 2008). *P. antipodarum* and its impacts are similar to that of the extremely problematic invasive Zebra Mussel (*Dreissena polymorpha*) (National Park Service [2003])."

"*P. antipodarum* can establish extremely dense populations of tens to hundreds of thousands of individuals per square meter in introduced environments. In Australia densities of 50,000 snails/m2 have been recorded (Ponder 1988; [Schreiber] et al, 1998). In the United States densities of 200,000, 500,000 and even 800,000 snails/m2 have been recorded in several locations (Davidson et al, 2008; Dorgelo, 1987 in Brown et al, 2008; Crosier et al, undated; Hall et al, [2003]; Levri et al, 2007)."

"These large populations undoubtedly have significant effects on ecosystems. *P. antipodarum* can consume up to 75% of gross primary production, dominate secondary production by composing up to 97% of invertebrate biomass, and excreting 65% of total NH4 thereby dominating C and N cycles as in the case of Polecat Creek, Wyoming. Its secondary productivity is one of the highest ever reported (194 g AFDM m-2 yr-1), being 7–40 times higher than that of any macroinvertebrate in Greater Yellowstone area (Hall et al, 2003; Hall et al, 2006; Richards et al, 2002). Such alteration of ecosystems likely results in far reaching cascading ecological impacts (Crosier et al, undated; Davidson et al, 2008; Alonso & Castro-D[í]ez, 2008). It has also been indicated that it may increase CO2 levels by precipitating calcium bicarbonate to calcium carbonate to produce shells (Chavaud et al, 2003 in NZMS Working Group, 2006).
P. antipodarum may displace, inhibit growth in, and compete with native invertebrates for resources in introduced locations (Alonso & Castro-D[í]ez, 2008; Cowie et al, 2009; Davidson et al, 2008; Hall et al, 2006; Kerans et al, 2005). High densities of *P. antipodarum* were believed to have negative interactions with native macroinvertebrates in several locations in Montana (Kerans et al, 2005). In the Snake River, Idaho, its site of initial introduction in the United States,

it is believed to be a major cause of five species of native mollusks recently becoming endangered (Crosier et al, undated). This includes the endangered hydrobiid snail *Taylorconcha serpenticola* ([Richards 2004] in Brown et al, 2008). It is believed to limit absolute growth and the growth rate of the native desert valvata snail (*Valvata utahensis*) in the Snake River as well (Lysne & Koetsier, 2008). It dominates the Mont Saint-Michael Bay in western France and represented 80% of gastropods collected from all sites (Gerard et al, 2003). Similarly, P. antipodarum made up 83% of the mollusk community in a reservoir near an industrial area in Poland ([Lewin and Smolinski], 2006). *P. antipodarum* has been found to significantly inhibit growth in endemic snail *Pyrulopsis robusta* in Polecat Creek, Wymoing (Riley et al, 2008). A negative correlation has been demonstrated with *P. antipodarum* and important invertebrate species mayflies, stoneflies, caddisflies, and chironomids (Crosier et al, undated). It has also been to have a negative correlation with native hydrobiid snails in Tasmania (Pon[d]er, 1988). *P. antipodarum* directly affects fish by being a poor and mostly un-digestible food source. Although rainbow trout *Onchorynchus mykiss* and brown trout *Salmo trutta* were found to feed on *P. antipodarum* in a study, about 80% of those consumed passed through their system undigested (NZMS Working Group, 2006). Not only does *P. antipodarum* replace energetic food sources, but it is believed to inflict poor health and reduce survivorship in fish that consume it based the significantly worse condition of fish with *P. antipodarum* in their guts ([Vinson] & Baker, 2008)."

From Krist and Charles (2012):

"In a field experiment, we compared the ability to graze periphyton and the genera of diatoms removed by the invasive New Zealand mudsnail, *Potamopyrgus antipodarum*, a native caddisfly larva (*Brachycentrus* sp.), and a native mayfly nymph (*Ephemerella* sp.) over 1 week. *P. antipodarum* removed as much or slightly more periphyton than the native grazers, depending on whether chlorophyll a or ash-free dry mass was used to measure periphyton biomass. When we examined the diatoms in the periphyton, *P. antipodarum* altered the diatom assemblage more than the native grazers. Effective grazing of periphyton by *P. antipodarum* may impact native grazers by consuming shared algal resources. In particular, because *Ephemerella* sp. were also effective grazers, these mayflies may compete for periphyton with *P. antipodarum* in the western United States. Taken together, these results suggest that ability to procure food resources may contribute to the invasion success of *P. antipodarum*."

4 Global Distribution

Figure 1. Global distribution of *P. antipodarum*. Map from GBIF (2013).

5 Distribution within the United States

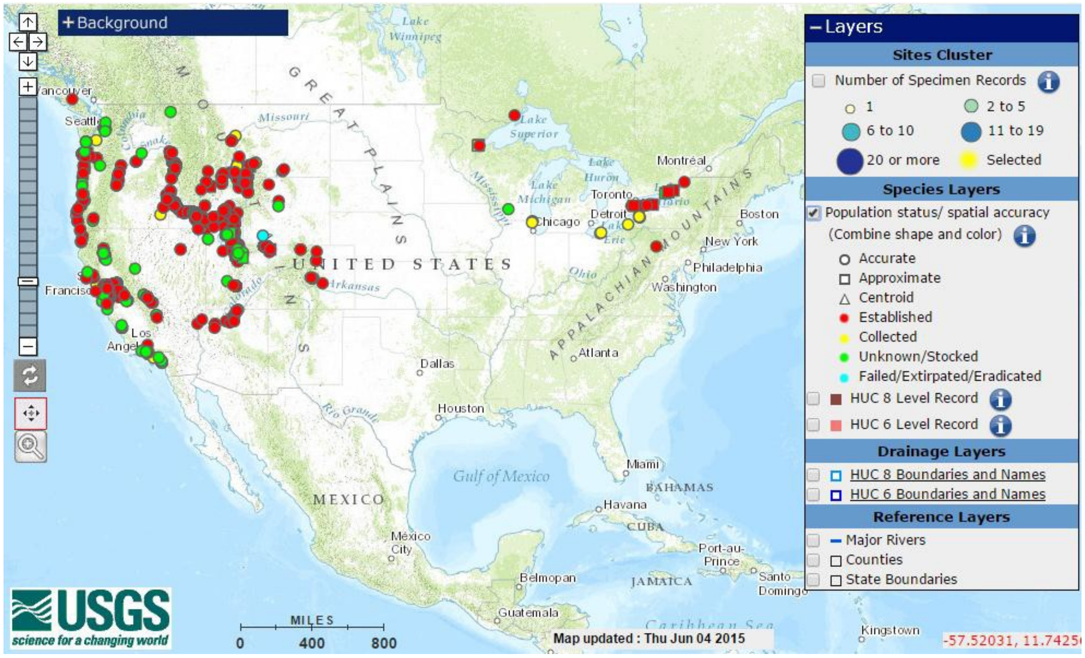

Figure 2. Distribution of *P. antipodarum* in the US. Map from Benson et al. (2015).

6 Climate Match

Summary of Climate Matching Analysis

The climate match (Sanders et al. 2014; 16 climate variables; Euclidean Distance) was high for the West, Midwest, and Northeast regions of the contiguous US. The climate match was low for the Southeast, from Virginia to eastern Texas, and in isolated pockets in the Southwest and along the Atlantic and Pacific coasts. Climate 6 match indicated that the US has a high climate match. The range for a high climate match is 0.103 and greater, climate match of *P. antipodarum* is 0.763.

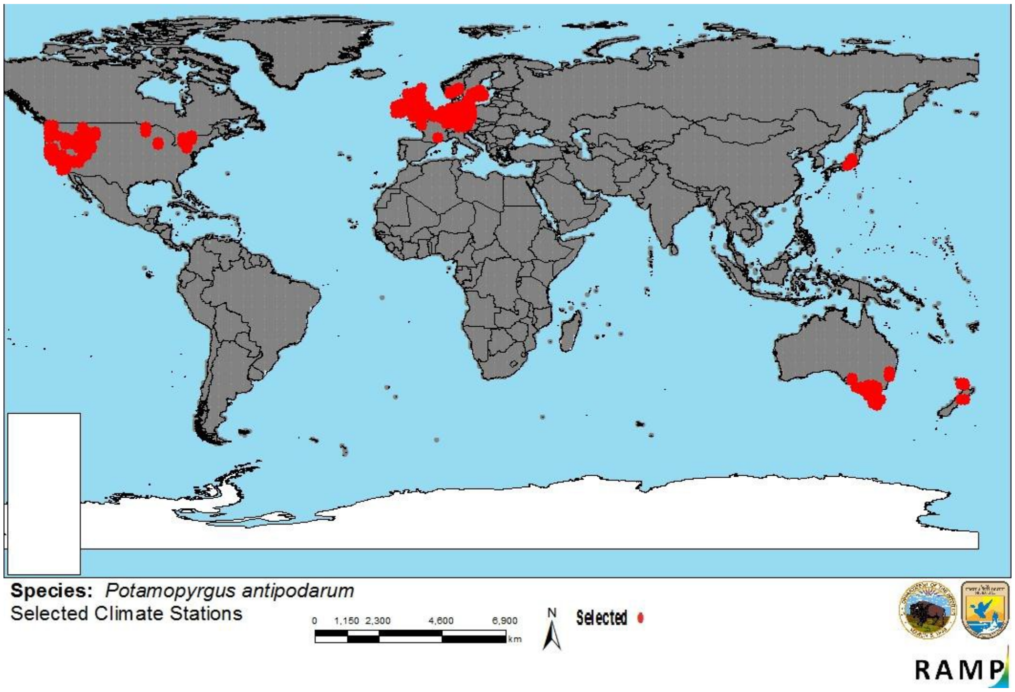

Figure 3. RAMP (Sanders et al. 2014) source map showing weather stations selected as source locations (red) and non-source locations (gray) for *P. antipodarum* climate matching. Source locations from GBIF (2013) and Benson et al. (2015).

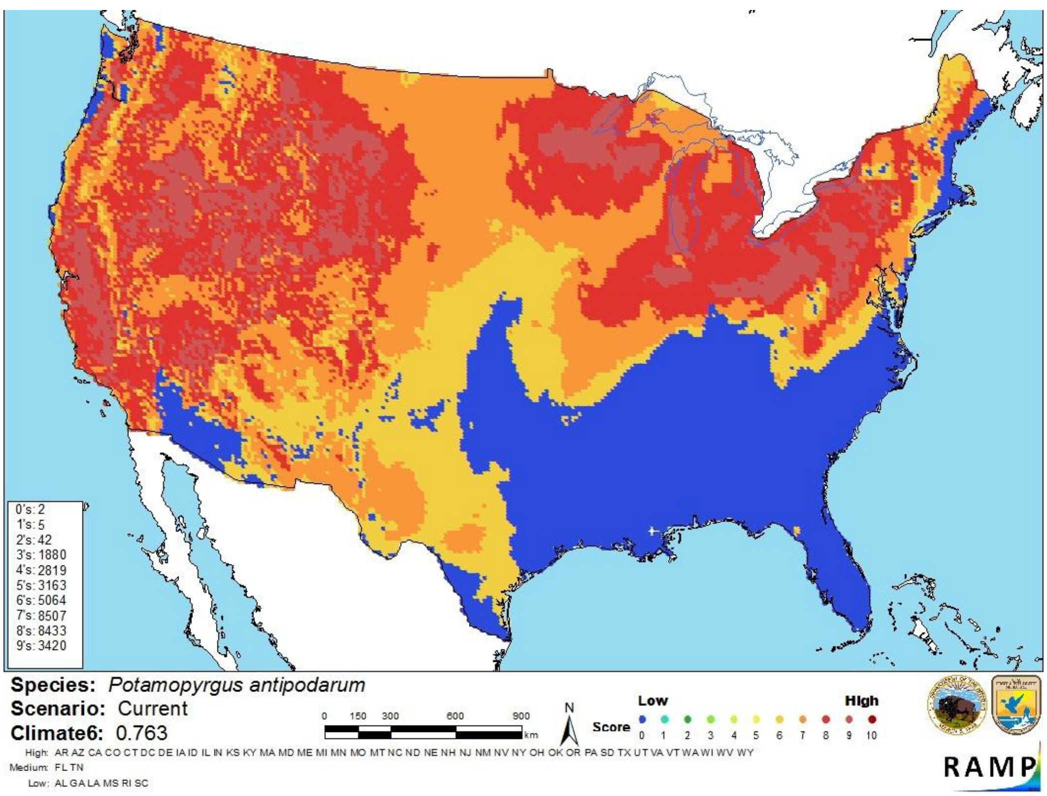

Figure 4. Map of RAMP (Sanders et al. 2014) climate matches for *P. antipodarum* in the continental United States based on source locations reported by GBIF (2013) and Benson et al. (2015). 0= Lowest match, 10=Highest match.

7 Certainty of Assessment

Information on the biology, distribution, and impacts of *P. antipodarum* is readily available. Negative impacts from introductions 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

P. antipodarum, native to New Zealand, has been introduced to Europe, Asia, North America, and Australia. Its small size, ability to withstand dessication and temperature variation, and parthenogenic reproduction facilitate its accidental introduction and establishment in new locations. The species can be found living in extremely high densities (tens of thousands per square meter) in some locations. Negative impacts have been documented on native macroinvertebrates, mollusks, and fish. Its impacts have been likened to those of the zebra mussel (*Dreissena polymorpha*). Climate match with the contiguous US is high. Overall risk for this species is high.

Assessment Elements

- **History of Invasiveness (Sec. 3):** High
- **Climate Match (Sec. 6):** High
- **Certainty of Assessment (Sec. 7):** High
- **Important additional information:** Parthenogenic
- **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., R. M. Kipp, J. Larson, and A. Fusaro. 2015. *Potamopyrgus antipodarum*. USGS Nonindigenous Aquatic Species Database, Gainesville, Florida. Available: http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=1008. (June 2015).

CABI. 2015. *Potamopyrgus antipodarum* (New Zealand mudsnail) [original text by A. Alonso]. Invasive Species Compendium. CAB International, Wallingford, UK. Available: http://www.cabi.org/isc/datasheet/43672. (June 2015).

Global Biodiversity Information Facility (GBIF). 2013. GBIF Backbone Taxonomy: *Potamopyrgus antipodarum* (J. E. Gray, 1853). Global Biodiversity Information Facility, Copenhagen. Available: http://www.gbif.org/species/5192470. (June 2015).

Global Invasive Species Database (GISD). 2011. *Potamopyrgus antipodarum* (mollusc). IUCN Invasive Species Specialist Group, Gland, Switzerland. Available: http://www.issg.org/database/species/ecology.asp?si=449&fr=1&sts=sss&lang=EN. (June 2015).

Integrated Taxonomic Information System (ITIS). 2015. *Potamopyrgus antipodarum* (J. E. Gray, 1853). Integrated Taxonomic Information System, Reston, Virginia. Available: http://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=205006. (June 2015).

Krist, A. C., and C. C. Charles. 2012. The invasive New Zealand mudsnail, *Potamopyrgus antipodarum*, is an effective grazer of algae and altered the assemblage of diatoms more than native grazers. Hydrobiologia 694(1):143-151.

Sanders, S., C. Castiglione, and M. Hoff. 2014. Risk Assessment Mapping Program: RAMP. US 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.

Alonso, A., and P. Castro-Díez. 2008. What explains the invading success of the aquatic mudsnail *Potamopyrgus antipodarum* (Hydrobiidae, Mollusca)? Hydrobiologia 614:107-116.

Broekhuizen, N., S. Parkyn, and D. Miller. 2001. Fine sediment effects on feeding and growth in the invertebrate grazer *Potamopyrgus antipodarum* (Gastropoda, Hydrobiidae) and *Deleatidium* sp. (Ephemeroptera, Letpophlebiidae). Hydrobiologia 457(1–3):125–132.

Brown, K. M., B. Lang, and K. E. Perez. 2008. The conservation ecology of North American pleurocerid and hydrobiid gastropods. Journal of the North American Benthological Society 27(2):484-495.

Bruce, R. L. 2006. Methods of fish depuration to control New Zealand mudsnails at fish hatcheries. Masters thesis. University of Idaho, Moscow, Idaho.

Cejka, T., L. Dvorak, and V. Kosel. 2008. Present distribution of *Potamopyrgus antipodarum* (Gray, 1843) (Mollusca: Gastropoda) in the Slovak Republic. Malacologica Bohemoslovaca 7:21–25.

Chavaud, L., J. K. Thompson, J. E. Cloern, and G. Thouzeau. 2003. Clams as CO2 generators: the *Potamocorbula amurensis* example in San Francisco Bay. Limnology and Oceanography 48:2086-2092.

Collier, K. J., R. J. Wilcock, and A. S. Meredith. 1998. Influence of substrate type and physico–chemical conditions on macroinvertebrate faunas and biotic indices in some lowland Waikato, New Zealand, streams. New Zealand Journal of Marine and Freshwater Research 32(1):1–19.

Costil, K., G. B. J. Dussart, and J. Daquzan. 2001. Biodiversity of aquatic gastropods in the Mont St–Michel basin (France) in relation to salinity and drying of habitats. Biodiversity and Conservation 10(1):1–18.

Cotton, B. C. 1942. Some Australian freshwater Gastropoda. Transactions of the Royal Society of South Australia 66:75–82.

Cowie, R. H., R. T. Dillon, Jr., D. G. Robinson, and J. W. Smith. 2009. Alien non-marine snails and slugs of priority quarantine importance in the United States: a preliminary risk assessment. American Malacological Bulletin. 27(1-2):113-132.

Cox, T. J., and J. C. Rutherford. 2000. Thermal tolerances of two stream invertebrates exposed to diurnally varying temperature. New Zealand Journal of Marine and Freshwater Research 34(2):203–208.

Crosier, D. M., D. P. Molloy, and D. C. Richards. Undated. New Zealand mudsnail - *Potamopyrgus antipodarum*. Available from: http://el.erdc.usace.army.mil/ansrp/potamopyrgus_antipodarum.pdf. (March 2010).

Davidson, T. M., V. E. F. Brenneis, C. de Rivera, R. Draheim, and G. E. Gillespie. 2008. Northern range expansion and coastal occurrences of the New Zealand mud snail

Potamopyrgus antipodarum (Gray, 1843) in the northeast Pacific. Aquatic Invasions 3(3):349-353.

Death, R. G., B. Baillie, and P. Fransen. 2003. Effect of *Pinus radiata* logging on stream invertebrate communities in Hawke's Bay, New Zealand. New Zealand Journal of Marine and Freshwater Research 37(3):507–520.

Dorgelo, J. 1987. Density fluctuations in populations (1982–1986) and biological observations of *Potamopyrgus jenkinsi* in two trophically differing lakes. Hydrobiological Bulletin 21:95–110.

Dybdahl, M. F., and A. C. Krist. 2004. Genotypic vs. condition effects on parasite–driven rare advantage. Journal of Evolutionary Biology 17(5):967–973.

Gerard, C., A. Blanc, and K. Costil. 2003. *Potamopyrgus antipodarum* (Mollusca: Hydrobiidae) in continental aquatic gastropod communities: impact of salinity and trematode parasitism. Hydrobiologia 493(1–3):167–172.

Gerard, C., and J. Le Lannic. 2003. Establishment of a new host-parasite association between the introduced invasive species *Potamopyrgus antipodarum* (Smith) (Gastropoda) and *Sanguinicola* sp. Plehn (Trematoda) in Europe. Journal of Zoology 261(2):213-216.

Grigorovich, I. A., A. V. Korniushin, D. K. Gray, I. C. Duggan, I. R. Colautti, and H. J. MacIsaac. 2003. Lake Superior: an invasion coldspot? Hydrobiologia 499(1):191–210.

Hall, R. O. Jr., M. F. Dybdahl, and M. C. VanderLoop. 2006. Extremely high secondary production of introduced snails in rivers. Ecological Applications 16(3):1121-1131.

Hall, R. O. Jr., J. L. Tank, and M. F. Dybdahl. 2003. Exotic snails dominate nitrogen and carbon cycling in a highly productive stream. Frontiers in Ecology and the Environment 1(8):407-411.

Holomuzki, J. R., and B. J. F. Biggs. 1999. Distributional responses to flow disturbance by a stream–dwelling snail. Oikos 87(1):36–47.

Holomuzki, J. R., and B. J. F. Biggs. 2000. Taxon–specific responses to high–flow disturbances in streams: implications for population persistence. Journal of the North American Benthological Society 19(4):670–679.

Hosea, R. C., and B. Finlayson. 2005. Controlling the spread of New Zealand mud snails on wading gear. California Department of Fish and Game.

Jacobsen, R., and V. E. Forbes. 1997. Clonal variation in life–history traits and feeding rates in the gastropod, *Potamopyrgus antipodarum*: performance across a salinity gradient. Functional Ecology 11(2):260–267.

James, M. R., I. Hawes, and M. Weatherhead. 2000. Removal of settled sediments and periphyton from macrophytes by grazing invertebrates in the littoral zone of a large oligotrophic lake. Freshwater Biology 44(2):311–326.

JNCC 2002 [cited by GISD 2011, source did not provide full citation]

Jokela J., C. M. Lively, M. F. Dybdahl, and J. A. Fox. 1997. Evidence for a cost of sex in the freshwater snail *Potamopyrgus antipodarum*. Ecology 78:452-460.

Kelly, D.J., and I. Hawes. 2005. Effects of invasive macrophytes on littoral–zone productivity and foodweb dynamics in a New Zealand high–country lake. Journal of the North American Benthological Society 24(2):300–320.

Kerans, B. L, M. F. Dybdahl, M. M. Gangloff and J. E. Jannot. 2005. *Potamopyrgus antipodarum*: distribution, density, and effects on native macroinvertebrate assemblages in the Greater Yellowstone ecosystem. Journal of the North American Benthological Society 24(1):123–138.

Leppäkoski, E., and S. Olenin. 2000. Non–native species and rates of spread: lessons from the brackish Baltic Sea. Biological Invasions 2(2):151–163.

Levri, E. P. 1998. Perceived predation risk, parasitism, and the foraging behavior of a freshwater snail (*Potamopyrgus antipodarum*). Canadian Journal of Zoology 76(10):1878–1884.

Levri, E. P., A. A. Kelly, and E. Love. 2007. The invasive New Zealand mud snail (*Potamopyrgus antipodarum*) in Lake Erie. Journal of Great Lakes Research 33(1):1-6.

Lewin, I., and A. Smolinski. 2006. Rare and vulnerable species in the mollusc communities in the mining subsidence reservoirs of an industrial area (The Katowicka Upland, Upper Silesia, Southern Poland). Limnologica 36(3):181-191.

Lively, C. M., and J. Jokela. 2002. Temporal and spatial distribution of parasites and sex in a freshwater snail. Evolutionary Ecology Research 4(2):219–226.

Loo, S. E., R. P. Keller, B. Leung. 2007a. Freshwater invasions: using historical data to analyse spread. Diversity & Distributions 13(1):23-32.

Loo, S. E., R. Mac Nally, and P. S. Lake. 2007b. Forecasting New Zealand mudsnail invasion range: model comparisons using native and invaded ranges. Ecological Applications 17(1):181-189.

Lysne, S., and P. Koetsier. 2008. Comparison of desert valvata snail growth at three densities of the invasive New Zealand mudsnail. Western North American Naturalist 68(1):103-106.

National Park Service. 2003. New Zealand mud snail, baseline distribution and monitoring study. Department of the Interior. Available: http://www.nps.gov/yell/planyourvisit/mudsnail.htm. (October 2003).

Negovetic, S., and J. Jokela. 2000. Food choice behaviour may promote habitat specificity in mixed populations of clonal and sexual *Potamopyrgus antipodarum*. Experimental Ecology 60(4):435–441.

New Zealand Mudsnail Management and Control Working Group (NZMS Working Group). 2006. National management and control plan for the New Zealand mudsnail (*Potamopyrgus antipodarum*) DRAFT. Prepared for the Aquatic Nuisance Species Task Force by the New Zealand Mudsnail Management and Control Plan Working Group.

Parkyn, S. M., J. M. Quinn, T. J. Cox, and N. Broekhuizen. 2005. Pathways of N and C uptake and transfer in stream food webs: an isotope enrichment experiment. Journal of the North American Benthological Society 24(4):955–975.

Ponder, W. F. 1988. *Potamopyrgus antipodarum* - a Molluscan colonizer of Europe and Australia. Journal of Molluscan Studies 54:271-285.

Richards, D. C. 2004. Competition between the threatened Bliss Rapids snail *Taylorconcha serpenticola* (Hershler et al.) and the invasive, aquatic snail, *Potamopyrgus antipodarum* (Gray). Doctoral dissertation. Montana State University, Bozeman, Montana.

Richards, D. C., L. D. Cazier, and G. T. Lester. 2001. Spatial distribution of three snail species, including the invader *Potamopyrgus antipodarum*, in a freshwater spring. Western North American Naturalist 61(3):375–380.

Richards, D., B. Kerans, and D. Gustafson. 2002. New Zealand mudsnail in the Western USA. Montana State University: Department of Ecology. Available: http://www.esg.montana.edu/aim/mollusca/nzms/. (October 2003).

Richards, D. C., P. O'Connell, and D. C. Shinn. 2004. Simple control method to limit the spread of the New Zealand mudsnail *Potamopyrgus antipodarum*. North American Journal of Fisheries Management 24:114-117.

Riley, L. A., M. F. Dybdahl, and R. O. Hall, Jr. 2008. Invasive species impact: asymmetric interactions between invasive and endemic freshwater snails. Journal of the North American Benthological Society 27(3):509-520.

Schreiber, E. S. G., A. Glaister, G. P. Quinn, and P. S. Lake. 1998. Life history and population dynamics of the exotic snail *Potamopyrgus antipodarum* (Prosobranchia: Hydrobiidae) in Lake Purrumbete, Victoria, Australia. Marine and Freshwater Research 49(1):73–78.

Schreiber, E. S. G., P. S. Lake, and G. P. Quinn. 2002. Facilitation of native stream fauna by an invading species? Experimental investigation of the interaction of the snail, *Potamopyrgus antipodarum* (Hydrobiidae) with native benthic fauna. Biological Invasions 4(3):317–325.

Schreiber, E. S. G., G. P. Quinn, and P. S. Lake. 2003. Distribution of an alien aquatic snail in relation to flow variability, human activities and water quality. Freshwater Biology 48(6):951–961.

Strzelec, M. 2005. Impact of the introduced *Potamopyrgus antipodarum* (Gastropods) on the snail fauna in post–industrial ponds in Poland. Biologia (Bratislava) 60(2):159–163.

Suren, A. M. 2005. Effects of deposited sediment on patch selection by two grazing stream invertebrates. Hydrobiologia 549(1):205–218.

U.S. Environmental Protection Agency (USEPA). 2008. Predicting future introductions of nonindigenous species to the Great Lakes. National Center for Environmental Assessment, Washington, DC. EPA/600/R-08/066F. Available from the National Technical Information Service, Springfield, VA, and http://www.epa.gov/ncea.

U.S. Fish and Wildlife Service (USFWS). 2005. National Wildlife Refuge System Invasive Species. Available: http://www.fws.gov/invasives/nwrs.html. (2006).

Vinson, M. R., and M. A. Baker. 2008. Poor growth of rainbow trout fed New Zealand mud snails *Potamopyrgus antipodarum*. North American Journal of Fisheries Management 28(3):701-709.

Weatherhead, M. A., and M. R. James. 2001. Distribution of macroinvertebrates in relation to physical and biological variables in the littoral zone of nine New Zealand lakes. Hydrobiologia 462(1–3):115–129.

Winterbourn, M. J. 1973. A guide to the freshwater mollusca of New Zealand. Tuatara 20:141-158.

Zaranko, D. T., D. G. Farara, and F. G. Thompson. 1997. Another exotic mollusk in the Laurentian Great Lakes: the New Zealand native *Potamopyrgus antipodarum* (Gray 1843) (Gastropoda, Hydrobiidae). Canadian Journal of Fisheries and Aquatic Sciences 54(4):809-814.

Zbikowski, J., and E. Zbikowska. 2009. Invaders of an invader - trematodes in *Potamopyrgus antipodarum* in Poland. Journal of Invertebrate Pathology 101(1):67-70.