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Frances E. Lucy and Thaddeus K. Graczyk (Guest Editors)

Short communication

Northern range expansion and coastal occurrences of the New Zealand mud snail *Potamopyrgus antipodarum* (Gray, 1843) in the northeast Pacific

Timothy M. Davidson[1*], Valance E. F. Brenneis[2], Catherine de Rivera[1], Robyn Draheim[1] and Graham E. Gillespie[3]
[1]*Aquatic Bioinvasion Research and Policy Institute, Department of Environmental Sciences & Management, Portland State University, PO BOX 751, Portland, Oregon, USA 97207*
[2]*Department of Environmental Science & Policy, University of California, Davis, One Shields Avenue, Davis, CA, USA 95616*
[3]*Fisheries and Oceans Canada, Marine Ecosystems and Aquaculture Division, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, British Columbia, Canada V9T 6N7*
**Corresponding author*
E-mail: tid@pdx.edu

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Abstract

The New Zealand mud snail *Potamopyrgus antipodarum* (Gray, 1843) is a common invasive species in fresh and brackish water ecosystems in Europe, Australia, Japan, and North America. In some invaded habitats, *P. antipodarum* can reach high densities (over 500,000 snails m^{-2}) and dominate the biomass of the benthos, leading to detrimental impacts to native biota and changes in ecosystem dynamics. We report the previously unpublished occurrence of *P. antipodarum* in thirteen fresh and brackish water systems adjacent to the Pacific coast of North America including a new northern range for *P. antipodarum*: Port Alberni, Vancouver Island, British Columbia, Canada (49.2479º, -124.8395º). We hypothesize the snail was spread from the Columbia River Estuary to Port Alberni via recreational watercraft or infected fishing equipment. Its discovery in Port Alberni reveals the potential for other aquatic nuisance species in the lower Columbia River to spread to British Columbia. Resource managers on the Pacific coast should remain vigilant and educate the public to prevent the further spread of the *P. antipodarum* as well as other aquatic invaders.

Key words: brackish gastropods, British Columbia, New Zealand mud snail, Port Alberni, *Potamopyrgus antipodarum*, range expansion, Vancouver Island

The New Zealand mud snail *Potamopyrgus antipodarum* (Gray, 1843) is a global invader present in several continents including Europe (Bondesen and Kaiser 1949), Tasmania and mainland Australia (Ponder 1988), Asia (Shimada and Urabe 2003) and North America (Bowler 1991). The hydrobiid snail is native to New Zealand and is distinguishable from other snails by the presence of an operculum, 5-6 body whorls often harboring a weak keel or carina and brooded young (Winterbourn 1970). They are very small (5-6mm in length) and may be found subtidally or intertidally on or under rocks and debris in fresh or brackish waters. *Potamopyrgus antipodarum* can be spread anthropogenically through movement of gear such as waders, boots, angling equipment, and boats or by the translocation of aquaculture materials (live fish or eggs; Bowler 1991; Haynes et al. 1985; Hosea and Finlayson 2005). Secondary introductions may occur on birds that carry the snails among their feathers or by fish that consume but are unable to digest snails (Bondesen and Kaiser 1949; Haynes et al. 1985).

In some invaded freshwater systems, *P. antipodarum* has become the most prevalent and numerically abundant species (Ponder 1988; Hall et al. 2006) reaching densities over 500,000 snails m^{-2} in vegetative and muddy substrates, and constituting between 65-92% of total invertebrate productivity (Hall et al. 2006). These herbivorous and detritivorous snails can also dominate carbon and nitrogen fluxes (Hall et al. 2003). The high densities achieved by *P. antipodarum* in invaded systems suggest that it may compete with native species for resources (Brown et al. 2008). However, the field evidence for a negative competitive effect is mixed, with some negative (Kerans et al. 2005), non-significant (Cada 2004) and positive (Schreiber 2002) correlations between densities of *P. antipodarum* and native fauna. *Potamopyrgus antipodarum* may also reduce the colonization rate of some macroinvertebrates (Kerans et al. 2005) and affect the survivorship of fish that consume them (Vinson and Baker 2008). The interactions with different trophic levels coupled with the high densities observed in many systems may lead to substantial changes in trophic dynamics and nutrient cycling in aquatic ecosystems (Bronmark 1989; Hall et al. 2003; Hall et al. 2006).

While *P. antipodarum* is usually described as a freshwater invader in North America, this species is being increasingly found in brackish estuarine environments and adjacent aquatic habitats (Bersine et al. 2008). We report occurrences of this invasive snail from a series of qualitative surveys and verified sightings in coastal aquatic systems of the northeast Pacific. Our surveys revealed several new invasions of brackish and freshwater environments by *P. antipodarum* including a new northern limit on the northeast Pacific coast for the invasive mud snail. *Potamopyrgus antipodarum* was discovered in Port Alberni Inlet (5 salinity), Vancouver Island, British Columbia during surveys conducted in July 2007. The snails occur in low densities amongst intertidal woody debris in areas adjacent (<1 km) to the primary marina and boat ramp for the town of Port Alberni. We also report twelve occurrences in the brackish and fresh water environments of Oregon and Washington, USA (Figure 1, Annex 1).

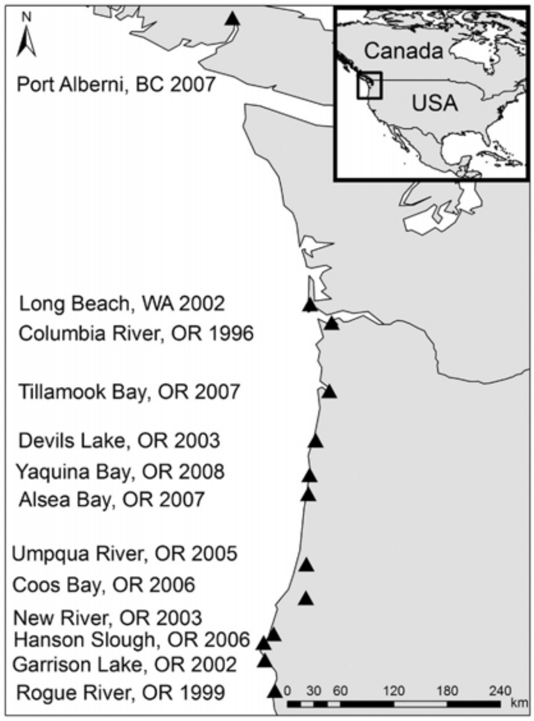

Figure 1. Occurrences of *Potamopyrgus antipodarum* (▲) in aquatic systems of the coastal region of the northeast Pacific. The year of discovery is noted. BC= British Columbia (Canada), WA = Washington (USA), OR = Oregon (USA)

We hypothesize that the well-established population of *P. antipodarum* in the Columbia River Estuary is the source of the snails found in Port Alberni. This hypothesis is supported by four main lines of evidence. 1) *P. antipodarum* occurs in very high densities (over 200,000 snails/m^2; Litton 2000) in the Columbia River Estuary and has been there at least since 1996 (Bersine et al. 2008). 2) The lower Columbia River Estuary hosts many recreational sport fisheries and boaters, which are likely vectors for *P. antipodarum* (Bowler 1991; Haynes et al. 1985; Hosea and Finlayson 2005). 3) Port Alberni is also a popular destination for recreational fishers and boaters (G. Gillespie, per. obs.). 4) *P. antipodarum* is highly tolerant to desiccation and can survive over 50 days on a wet substrate (Winterbourn 1970). Despite the large separation in physical distance between Port Alberni and the Columbia River Estuary (driving distance: 565 km, 9 hours driving), *P. antipodarum* could survive the transit in damp fishing gear, boating equipment, or on vegetation and mud attached to the hulls of boats and trailers. It is unlikely these snails were introduced to Port Alberni from the populations in Long Beach, Washington or other Oregon sites since many of these sites harbor lower densities of *P. antipodarum* (unpublished data) and are utilized by fewer recreational fishers and boaters compared to the Columbia River Estuary. The invasion of the Columbia River Estuary by *P. antipodarum* is thought to be a secondary introduction from the interior of the western USA since both populations exhibit the same clonal lineage (Dybdahl and Kane 2005). Thus, genetic analysis of the Port Alberni populations would reveal if this population is a new clone (new invasion from New Zealand or Australia) or of the same clonal lineage (secondary introduction). *Potamopyrgus antipodarum* could also invade locations north of Port Alberni. Using Genetic Algorithm for Rule-set Production (GARP), Loo et al. (2007) predicted *P. antipodarum* might be distributed in areas many kilometers north of Port Alberni due to its wide range of temperature and salinity tolerance.

The discovery of *P. antipodarum* in Port Alberni reveals the potential for further invasions of the numerous other non-native aquatic species present in the lower Columbia River, if this new population is sourced from there. The lower Columbia River receives a large volume of international and regional ship traffic and hosts over 54 non-native species (Sytsma et al. 2004) including several that could be transported similarly and can drastically alter aquatic habitats (e.g. Eurasian watermilfoil *Myriophyllum spicatum* [Linnaeus, 1753] and common reed *Phragmites australis* [Cav.] Trin. ex Steud). Thus, it is important to recognize the role of intraregional traffic (such as recreational boaters) in spreading invasive species initially introduced through commercial shipping (Wasson et al. 2001). This invasion also elucidates the importance of international cooperation in preventing and reporting the spread of aquatic invaders across international borders.

Due to their small size, resistance to desiccation, and parthenogenetic reproduction, there appear to be few (if any) feasible options in controlling *P. antipodarum* populations once they become established (New Zealand Mudsnail Management and Control Plan Working Group 2007). Resource managers, however, are employing several options to prevent the future spread of *P. antipodarum* such as posting signs at boat ramps, distributing informational media (pamphlets, brochures, websites; pers. obs.), and by establishing permanent and mobile washing stations at boat ramps (New Zealand Mudsnail Management and Control Plan Working Group 2007). Another option is to treat infected equipment. Richards et al. (2004) recommended two options to prevent the spread of *P. antipodarum* through infected equipment: 1) freezing for several hours or 2) drying infected equipment at 30ºC for at least 24 hours or at 40ºC for 2 hours. There are also several chemical options to decontaminate infected equipment including copper sulfate (252 mg/L Cu), Formula 409® Disinfectant (50% dilution), and benzethonium chloride compounds (1,940 mg/L; Hosea and Finlayson 2005). These types of chemical treatments only require five minutes of submergence to be effective and do not appear to damage neoprene and rubber wading gear, although care must be taken to dispose of those chemicals properly (Hosea and Finlayson 2005). While chemical options are effective in preventing the spread of *P. antipodarum*, knowledge of infested sites coupled with rigorous gear cleaning (scrubbing, draining, and drying) at these sites and elsewhere are cost effective means of limiting further transport of *P. antipodarum* and other aquatic invasive species. We urge resource managers to remain vigilant and aware of the threat *P. antipodarum* may hold for aquatic systems and to educate the public in order to prevent the further spread of *P. antipodarum* on the Pacific coast of North America.

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Annex 1

Occurrences of *Potamopyrgus antipodarum* in the coastal region of the northeast Pacific

Location	Record coordinates		Date of record	Collector and affiliation or Reference
	Latitude,°N	Longitude,°W		
Port Alberni	49.2479	-124.8395	5.07.2007	Timothy M Davidson, Portland State University
Long Beach, Surfside drainage canal[1]	46.5343	-124.0547	Spring 2002	Washington Department of Fish and Wildlife
Columbia River, Youngs Bay	46.1643	-123.8388	Mar-1996	Clatsop Economic Development Council Fisheries Project, Oregon
Tillamook Bay	45.4709	-123.8610	29.10.2007	Sarah Miller, Oregon Department of Environmental Quality
Devils Lake	44.9707	-123.9989	23.08.2003	John W Chapman, Oregon State University
Yaquina Bay	44.6040	-123.9024	2.06.2008	James T Carlton, Williams College
Alsea Bay[1]	44.4288	-124.0443	Oct-2007	John W Chapman, Oregon State University
Umpqua River	43.7155	-124.0937	6.09.2005	Timothy M Davidson, Portland State University
Coos Bay	43.3733	-124.0989	24.12.2006	Timothy M Davidson, Portland State University
New River	43.0094	-124.4239	22.09.2003	Henry Lee II, Environmental Protection Agency
Hanson Slough	42.9206	-124.5239	29.06.2006	Erin Minster, South Coast Watershed Council
Garrison Lake	42.7510	-124.4996	2.07.2002	Alice Pfand, Volunteer for Portland State University
Rogue River	42.4325	-124.4114	31.08.1999	Larry Caton, Oregon Department of Environmental Quality

[1]Latitude and Longitude are approximations, exact record coordinates are unavailable