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Moluscos dulceacuícolas no nativos de México: estado actual y nuevos registros

Non-native freshwater mollusks in Mexico: current status and new records

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RESUMEN

Los moluscos dulceacuícolas encabezan, por un lado, las listas de especies amenazadas y en peligro de extinción y, por otro, las listas de especies no nativas potencialmente adversas para la fauna local. Así, la introducción, establecimiento y proliferación de especies no nativas de moluscos dulceacuícolas ha generado impactos significativos en la estructura y función de los ecosistemas acuáticos, alterando patrones de alimentación, de competencia por recursos y desencadenando efectos cascada en la cadena trófica local. México es un país vulnerable a estas especies ya que cuenta con una infraestructura de navegación que facilita su introducción. El auge de especies exóticas como mascotas y la introducción de especies económicamente atractivas para la explotación artesanal en ciertos cuerpos de agua incrementa el riesgo. Este trabajo presenta una lista actualizada de especies de gasterópodos y bivalvos dulceacuícolas no nativos / exóticos a través de revisión de registros geográficos en la literatura, registros en la Colección Nacional de Moluscos y aplicaciones de ciencia ciudadana. Se recopiló la literatura reciente con nuevos registros de especies exóticas. Se encontraron 13 especies exóticas de moluscos. Se procesaron 496 registros, siendo San Luis Potosí el estado con mayor ocurrencia y Veracruz el de mayor diversidad de especies exóticas. Todos los estados de México, con la excepción de Campeche y Tlaxcala, tienen por lo menos un registro de especies exóticas. La mayoría tiene impactos ecológicos, económicos o clínicos, algunas se encuentran catalogadas dentro las 100 especies exóticas-invasoras más indeseables. El acuarismo se ha identificado como el probable vector de introducción principal. Pueden existir nuevas invasiones no registradas en el país.

Palabras clave: Invasora, Exótica, Gastropoda, Bivalvia, Ciencia ciudadana.

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ABSTRACT

Background. Freshwater mollusks top the lists of both threatened and endangered species, as well as non-native species potentially harmful to local fauna. The introduction, establishment, and proliferation of non-native freshwater mollusk species have caused significant impacts on the structure and function of aquatic ecosystems, altering feeding patterns, resource competition, and triggering cascading effects throughout local trophic chains. Mexico is particularly vulnerable to these species due to its navigational infrastructure, which facilitates their introduction. The rising popularity of exotic species as pets and the intentional introduction of economically attractive species for artisanal exploitation in certain water bodies further increases the risk. Goals. This study aims to present an updated list of non-native/exotic freshwater gastropod and bivalve species. Methods. Occurrence data was based on a review of geographic records in the literature, data from the National Mollusk Collection, and citizen science platforms. Results. Recent literature revealed new records of exotic species. A total of 13 non-native mollusk species were identified. A total of 496 records were compiled, with the state of San Luis Potosí showing the highest occurrence, and Veracruz the greatest diversity of exotic species. All Mexican states, except Campeche and Tlaxcala, have at least one record of non-native species. Conclusions. Most of these species have ecological, economic, or health impacts, with some classified among the 100 worst invasive exotic species. The aquarium trade has been identified as the main probable vector of introduction. It is also likely that unrecorded invasions exist within the country.

Keywords: Invasive, Exotic, Gastropoda, Bivalvia, Citizen science.

INTRODUCTION

Freshwater mollusks, comprised by both bivalves and gastropods, are among the most threatened animal groups on the planet (Lydeard *et al.*, 2004; Strong *et al.*, 2008; Cowie *et al.*, 2017; Lydeard & Cummings, 2019; Cowie *et al.*, 2023). Both classes of mollusks are sensitive to changes in flow regimes, sedimentation, and pollution (Strong *et al.*, 2008). Many of these organisms belong to endemic species with restricted distributions and are highly vulnerable to global extinctions due to the loss of the water bodies in which they occur, such as cenotes, springs, small and isolated ponds, as well as lakes and rivers (Schmitter-Soto, 2002; Covich, 2010).

Freshwater mollusks are inefficient competitors against introduced species, which can be a potential threat by altering established assemblages and quickly invading new habitats (Covich, 2010; Cowie *et al.*, 2017). Less tolerant native species are at disadvantage when facing multiple factors, which can lead to their local extirpation (Czaja *et al.*, 2023).

Mexico is vulnerable to the introduction of exotic species due to its navigational infrastructure, which facilitates their entry. This includes human activities along continental margins as well as in bays and estuaries in the coastal zone (Naranjo-García & Castillo-Rodríguez, 2017). Other vectors for the introduction of exotic mollusks include international trade and the aquarium trade.

The most recent review of exotic mollusks in Mexico was based on records from biological collections, information on species arriving at U.S. customs, and literature (Naranjo-García & Castillo-Rodríguez, 2017). Meanwhile, over the last decade, citizen science platforms and digital repositories of global collections have provided important data on non-native species, especially in understudied areas (Tiemann *et al.*, 2024).

This work presents an updated list of non-native freshwater gastropod and bivalve species recorded in Mexico, defining an exotic or non-native species as any that has been introduced into a geographic area where it did not historically occur.

MATERIALS AND METHODS

To compile the list of exotic mollusk species in Mexico, we examined specimens of exotic mollusks deposited in the Colección Nacional de Moluscos (CNMO) Instituto de Biología, Universidad Nacional Autónoma de México. In addition, a systematic search of recent literature (January 2014–November 2024) was carried out through Web of Science, Science Direct, PubMed, Google, and Google Scholar using the keywords "exotic" or "new record" or "invasive" and "mollusk" or "mussel" or "snail" or "gastropod" or "bivalve" or "freshwater" and "Mexico," interchanging the terms in both English and Spanish.

Once the species list was obtained, occurrence data were downloaded from the GBIF platform (2024). iNaturalist records were curated to the family or genus level directly on the platform, and their coordinates were downloaded. Records with missing information (e.g., absence of coordinates) or inconsistent information (e.g., contradictory locality and coordinates), as well as records with poor-quality photographs, were excluded according to Tiemann *et al.* (2024). The potential introduction pathways and the ecological, economic, and health impacts of these species were documented based on the literature (Lowe *et al.*, 2000; Darrigran *et al.*, 2002; Rawlings *et al.*, 2007; Naranjo-García & Castillo-Rodríguez, 2017; Lu *et al.*, 2018; Czaja *et al.*, 2023; Tiemann *et al.*, 2024).

RESULTS

A total of 13 exotic freshwater mollusk species were identified in Mexico (Table 1). The systematic search of recent literature yielded eight studies reporting new records since the Naranjo-García & Castillo-Rodríguez (2017) publication (Wakida-Kusunoki *et al.*, 2015; Barba-Macías & Trinidad-Ocaña, 2017; Trinidad-Ocaña *et al.*, 2017; Raz-Guzmán, 2019; Tinajero *et al.*, 2018; López *et al.*, 2019; Tiemann *et al.*, 2020; 2024). A total of 496 records were obtained—202 from preserved specimens or from citations in GBIF (2024) and 294 from iNaturalist. Most of Mexican states, with the exception of Campeche and Tlaxcala, have at least one record of freshwater mollusks. The state of San Luis Potosí, with 61 records, showed the highest occurrence of exotic species in the GBIF (2024) database (Figure 1). Veracruz recorded the greatest number of exotic species, with a total of six (Table 1). The species *Marisa cornuarietis* (Linnaeus, 1758), commonly known as Ram horn snail, is reported for the first time in the country, in Quintana Roo.

On citizen science platforms, specimens of the family Thiaridae Gill, 1871 (1823) have been recorded in most Mexican states, except for Campeche, Nayarit, Tlaxcala, and Zacatecas. New records of *Tarebia granifera* (Lamarck, 1816) and *Melanoides tuberculata* (O. F. Müller, 1774) have been deposited in the CNMO from the state of Hidalgo, within some tributaries of the Tula River.

According to collection records and citizen science data, *Pomacea* Perry, 1810 specimens currently occur, outside their native distribution, in the northern and Pacific states of Mexico, including Baja California, Mexico City, Colima, Estado de México, Guerrero, Jalisco, Morelos, Nayarit, Sinaloa and Sonora.

DISCUSSION

Aquarium trade is the main source of exotic mollusk introductions in Mexico, serving as the probable vector for 11 out of the 13 species recorded in this study. Globally, aquarium trade has introduced one-third of the worst invasive species, and worldwide regulations to prevent their introduction are inadequate (Padilla & Williams, 2004). The exotic species *Pomacea canaliculata* (Lamarck, 1822) and *Dreissena polymorpha* (Pallas, 1771), occurring in México, are listed among the 100 worst invasive alien species (Lowe *et al.*, 2000).

The most widely distributed bivalve and gastropod species in Mexico are exotic, *Corbicula fluminea* (O. F. Müller, 1774) and *Melanoides tuberculata* (O. F. Müller, 1774) respectively. They have successfully established nearly all water bodies in the country, and their presence is consistently positively correlated with the absence of native species (Czaja *et al.*, 2023).

Eight exotic freshwater mollusk species in Mexico have been identified as potential hosts of parasites that cause human diseases. Among these, *Melanoides tuberculata* and *Tarebia granifera* warrant special attention due to their capacity to transmit the parasite *Paragonimus westermani* (Kerbert, 1878) (Lu *et al.*, 2018). In Mexico, cases

of paragonimiasis have been documented in endemic regions of the states of Nayarit, Colima, Michoacán, Veracruz, Tabasco, and Chiapas, associated with the parasite *Paragonimus mexicanus* Miyazaki & Ishii, 1968 (Lamothe-Argumedo *et al*., 1986). Although paragonimiasis is infrequent and difficult to diagnose, it can represent a public health concern in the country (Lamothe-Argumedo, 1986). To date, it has not been documented that the exotic mollusk species *M. tuberculata* and *T. granifera* serve as possible hosts for *P. mexicanus*; however, their spread due to a lack of control measures could imply public health risks (Gutiérrez-Gregoric & Vogler, 2010).

The species *Marisa cornuarietis*, a new record for Mexico, is a competitive feeder and voracious herbivore (Rawlings *et al*., 2007). The establishment of this species may pose a threat to native fauna in Quintana Roo (Esquivel-Blanco, 2024). Through iNaturalist, there is a photographic record of a shell resembling *M. cornuarietis* in Veracruz and Quintana Roo.

Radix auricularia (Linnaeus, 1758) had previously been recorded in 2017 (Naranjo-García & Castillo-Rodríguez, 2017) in Hidalgo, in the Tecocomulco Lake, and was subsequently deposited in the CNMO. In Rangel-Velasco's (2024) study, this species was not observed again, and the author suggests that it likely did not successfully establish in the lake.

The native distribution of the genus *Pomacea* extends from the Atlantic slope of the United States to Central America (Cowie & Thiengo, 2003; Naranjo-García, 2003), but it has been introduced into western Mexico by governmental institutions (Pineda-López *et al*., 2012). It is likely that the range expansion of *Pomacea* in Mexico has directly impacted the distribution of the bird species *Rostrhamus sociabilis* (Vieillot, 1817) and *Aramus guarauna* (Linnaeus, 1766), whose main diet is based on *Pomacea flagellata* (Say, 1829), and were previously unrecorded on Mexico's western coast (Palomera-García *et al*., 2006; Pineda-López *et al.,* 2012). Through iNaturalist, there is a photographic record of a shell resembling *Pomacea bridgesii* (Reeve, 1856) in Mexico City, indicating that this species may occur in Mexico and other parts of the country, given its frequent presence in the aquarium trade (Valdez- & Cruz-López, 2014).

It is an urgent necessity to implement preventive measures against the introduction of other exotic freshwater mollusk species. Some species that could expand their distribution and be introduced to Mexico through human activities include *Cipangopaludina chinensis* (J. E. Gray, 1833), *Limnoperna fortunei* (Dunker, 1857) and *Potamopyrgus antipodarum* (J. E. Gray, 1843), given the commercial ties and shared boundaries with the United States, where these species have been previously reported (CONABIO, 2017; Kingsbury *et al*., 2021). On the official Mexican channels (SEMARNAT, 2016), only eight freshwater mollusk species are enlisted, and one (*Limnoperna fortunei*) has not been previously recorded in the country.

It is also possible that current unreported invasions are already occurring in some states that have not been thoroughly studied, such

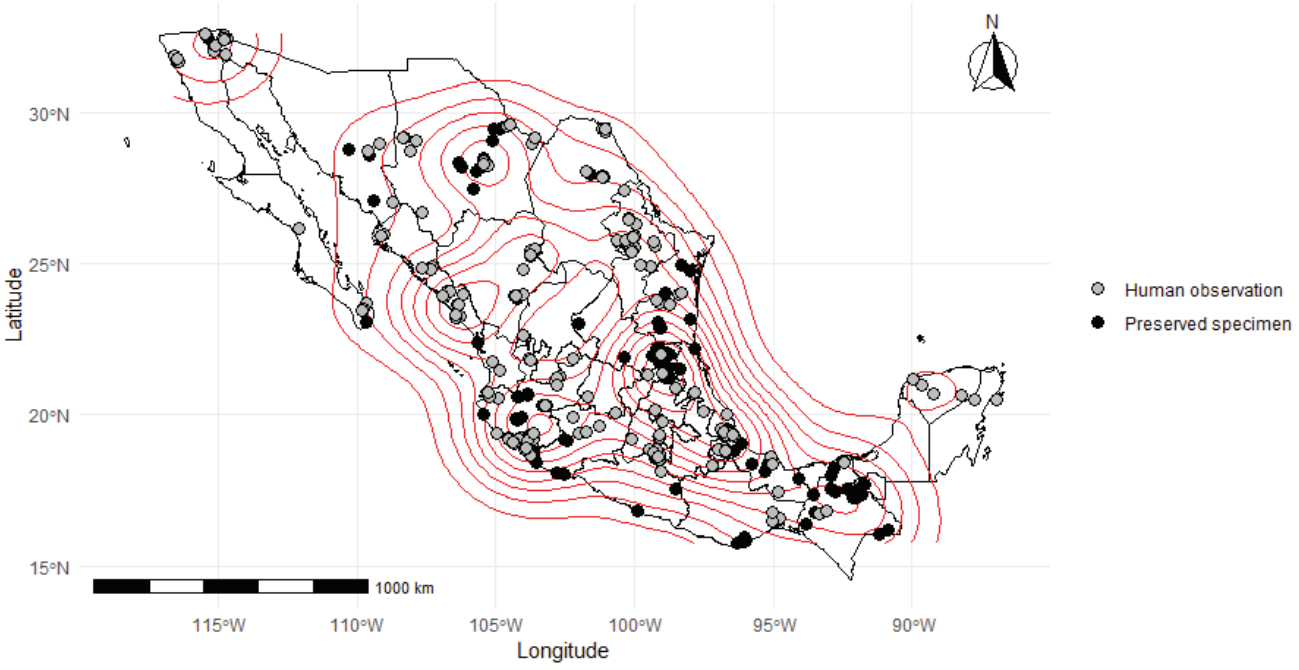

Figure 1. Occurrence of exotic freshwater mollusk species in Mexico from GBIF (2024). Data obtained as described in Materials and Methods. Density of occurrences is represented by kernel density estimation contours.

Table 1. Exotic freshwater species recorded in Mexico. AC=Aquaculture; AQ=Aquarism; TR=Trade.EC=Economic; EL=Ecological; HE= Health. AGS = Aguascalientes, BC = Baja California, BCS = Baja California Sur, CDMX = Mexico City, CHIH = Chihuahua, CHIS = Chiapas, COAH = Coahuila, COL = Colima, DGO = Durango, EDOMEX = Estado de México, GTO = Guanajuato, GRO = Guerrero, HGO = Hidalgo, JAL = Jalisco, MICH = Michoacán, MOR = Morelos, NAY = Nayarit, NL = Nuevo León, OAX = Oaxaca, PUE = Puebla, QR = Querétaro, QRO = Quintana Roo, SLP = San Luis Potosí, SIN = Sinaloa, SON = Sonora, TAB = Tabasco, TAMPS = Tamaulipas, VER = Veracruz, YUC = Yucatán, ZAC = Zacatecas. ND= No data

Class	Family	Species	Probable vector	Impact	Mexican states	Source
Bivalvia	Cyrenidae J. E. Gray, 1840	*Corbicula fluminea* (O. F. Müller, 1774)	AC, AQ	EC, EL, HE	BC, CHIH, CHIS, COAH, COL, DGO, GTO, GRO, HGO, JAL, EDOMEX, MICH, MOR, NAY, NL, OAX, PUE, QR, QRO, SLP, SIN, SON, TAB, TAMPS, VER, ZAC	CNMO; Naranjo-García & Castillo-Rodríguez, 2017; López *et al.*, 2018; Tiemann *et al.*, 2020; 2024
		Corbicula largillierti (R. A. Philippi, 1844)	AC, AQ	EC, EL, HE	BC, CHS, CHIH, COAH, COL, DGO, GTO, GRO, HGO, JAL, EDOMEX, MICH, NAY, NL, QRO, SIN, SON, TAB, TAMPS, VER	CNMO; Tiemann *et al.*, 2020; 2024
	Dreissenidae J. E. Gray, 1840	*Dreissena bugensis* Andrusov, 1897	TR	EC, EL, HE	BC	Wakida-Kusunoki *et al.,* 2015
		Dreissena polymorpha (Pallas, 1771)	TR	EC, EL, HE	VER	CNMO; Naranjo-García & Castillo-Rodríguez, 2017
Gastropoda	Ampullariidae J. E. Gray, 1824	*Marisa cornuarietis* (Linnaeus, 1758)	AQ	EL	QRO	CNMO
		Pomacea canaliculata (Lamarck, 1822)	AC, AQ	EC, EL, HE	BC	Naranjo-García & Castillo-Rodríguez, 2017
		Pomacea diffusa Blume, 1957	AC, AQ	ND	ND	Naranjo-García & Castillo-Rodríguez, 2017
		Pomacea flagellata (Say, 1829)	AC, AQ	EL	COL, GRO, JAL, MOR	Naranjo-García & Castillo-Rodríguez, 2017
	Thiaridae Gill, 1871 (1823)	*Melanoides tuberculata* (O. F. Müller, 1774)	AQ	EC, EL, HE	BCS, CHIS, CHIH, COAH, COL, GTO, GRO, HGO, MICH, MORE, QRO, TAMPS, TAB, VER, SIN, SLP, ZAC	CNMO; Naranjo-García & Castillo-Rodríguez, 2017; Trinidad-Ocaña *et al.*, 2017; Tinajero *et al.*, 2018; Raz-Guzmán, 2019;
		Tarebia granifera (Lamarck, 1816)	AQ	EC, EL, HE	CHIS, MICH, OAX, TAB, HGO, VER	CNMO; Naranjo-García & Castillo-Rodríguez, 2017
	Lymnaeidae Rafinesque, 1815	*Radix auricularia* (Linnaeus, 1758)	AQ	HE	HGO	Naranjo-García & Castillo-Rodríguez, 2017
	Planorbidae Rafinesque, 1815	*Planorbella duryi* (Wetherby, 1879)	AQ	ND	CDMX, TAB	Naranjo-García & Castillo-Rodríguez, 2017
		Amerianna carinata (H. Adams, 1861)	AQ	ND	ND	Naranjo-García & Castillo-Rodríguez, 2017

as Campeche and Tlaxcala. Periodic samplings are recommended in less-studied states and in remote sites, considering the vulnerability of native species in isolated water bodies. Likewise, it is advisable to monitor touristic water bodies, such as cenotes, since tourists can facilitate the introduction of species (Anderson *et al.*, 2015). Endemic fauna, often having evolved in isolation, may be less resilient to novel threats such as non-native species and the pathogens they may carry (Anderson *et al.*, 2015).

Citizen science platforms are an invaluable resource for recording and monitoring the distribution of species, and are especially important in the case of introduced ones. Some benefits of these platforms are that they raise environmental awareness, which has significant implications for increasing acceptance of biosecurity measures; they greatly enhance early detection capabilities and help track the spread and location of introduced species (Pyšek *et al.,* 2020). Additionally, the data collected in these platforms remain publicly accessible, and its potential application for scientific purposes ultimately depends on the user.

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