

ORIGINAL ARTICLE

MOLLUSKS OF AGRICULTURAL AND MEDICAL IMPORTANCE REGISTERED IN PORTS OF PANAMA, CENTRAL AMERICA

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ABSTRACT

We identified the species of land snails found in products exported from other countries, which could represent a danger to crops, animals, and the general population of our country and the Central American region. Specimens were collected at four points at each site, in the dry season (January to March 2008) and in the rainy season (April to December 2008 and 2009), twice a week each month. Diversity indices were used to determine species richness in the Caribbean (Province of Colón) and Pacific (Province of Panama) cargo ports. In total, 2,481 individuals of terrestrial mollusks were found, confirming the presence of *Allopeas gracile* (Hutton, 1834) in 10 cargo areas with $n=1,566$ (63.1%), most of them at Tocumen International Airport in the Pacific, Panama City, and with more activity in the rainy season. *Praticolella mexicana* was also reported for the first time in our country and is a terrestrial inhabitant of environments, frequently associated with open areas or important shrublands, for its role as an agricultural pest and as a potential vector of parasitic nematodes (such as *Angiostrongylus*) that affect humans and animals. In addition, more land snails were detected and collected in the loading areas of the ports in the rainy season. In the biodiversity indices, it was observed that there was no predominance of one species over the others. After this, it was concluded that the presence of these snails in our ports represents a critical challenge to bio-sanitary security in the region because it threatens food and agricultural security by producing economic losses and vulnerability of crops. The species found are invasive species, vectors of diseases that affect public health. It is necessary to have a lot of vigilance, which impacts the port biosecurity of the countries of the Central American region.

KEY WORDS: Biosecurity; invasive species; Gastropoda; Public Health.

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INTRODUCTION

The history of Panama's ports dates back more than 500 years, when the Spanish arrived in America and built the first port on the Pacific in 1519. Today, Panama has many ports, which are a fundamental part of the country's economy. The Port of Balboa, one of the most important in Panama and the largest on the Pacific, is located on the Pacific coast, at the entrance to the Panama Canal, making it the closest port to Asia. It is also a modern port that features the latest technology in cargo handling and has recently been expanded to meet the demands of the industry.

The Port of Colón, the largest port in the Caribbean and located at the entrance to the Panama Canal on the Atlantic coast, is a modern port with facilities for loading and unloading containers and solid grains. It is also the entry and exit point for most of the goods arriving and departing from Panama. The Port of Manzanillo is a small but important port on the Caribbean coast, located near the city of Colón and equipped with facilities for loading and unloading containers and bulk cargo. This port is also an important part of trade logistics in Panama. Due to its strategic location, the ports of Panama are the entry and exit points for most of the goods distributed throughout the region. Furthermore, the Panama Canal, the main means of transporting goods in the region, passes through the ports of Panama. Logistics and distribution are fundamental to Panama's economy; the ports of Panama serve as the entry and exit gateway for most of the goods arriving and leaving Latin America (The Logistic World, 2023).

The phylum Mollusca is the richest group in species after the arthropods, among which the squids, octopuses, clams, oysters, snails, and slugs stand out (Fuentes, 2006). They are found in almost all regions and habitats of the Earth. They feed on almost everything edible, from soil microorganisms and plankton to poisonous fungi, garden crops, garbage, paper, and living or decomposing terrestrial animals, and some are cannibals (Berg, 1994).

These lung-shaped mollusks, which include species with shells (snails) and others in which the shell is greatly reduced or absent, are divided into three broad orders: Stylommatophora (terrestrial and snails), Systelommatophora (groups of so-called seven-skinned snails), and Basommatophora (freshwater snails) (Berg, 1994; Monge-Nájera, 1996; Fuentes, 2006).

Many species of terrestrial mollusks are vectors of numerous diseases that affect humans, for which there are no vaccines, because many parasitic nematodes in their life cycles use terrestrial gastropods as intermediate hosts (Valente et al., 2020). Therefore, it is advisable to focus on the management and control of these mollusk populations and to carry out bioecological studies that enable their correct description (García et al., 2005).

Researchers such as Monge-Nájera (1996 and 2003), Iannacone et al. (2013a and b), Fimia et al. (2014a and b) and Vásquez and Cobian (2014),

have discovered that terrestrial mollusks living in the cargo zone not only cause economic damage, but also represent a potential risk to the health of producers and consumers, since they are intermediate hosts of different microorganisms that transmit harmful diseases to humans, since they act as vectors of parasites, especially nematodes and trematodes. These diseases are caused by changes in the climate and environment. Many studies have shown that these diseases are becoming more common and more dangerous due to climate change (Pointier and Jourdan, 2000; García et al., 2005; Hussein et al., 2011; Iturbe and Muñiz, 2011; Clausen et al., 2012; Abd El-Wakeil et al., 2013; Santos et al., 2014).

In addition to being a food source in Europe and Asia, many species are considered important agricultural pests and have therefore had a growing influence on international trade by acting as quarantine pests (Monge-Nájera, 2003). Invasive gastropods pose a significant threat to horticulture and agriculture in North America. Various species feed on plants, leading to decreases in both the yield and quality of agricultural products, thus affecting the profitability of numerous crops (Byers, 2002; Sakovich, 2002).

Land snails have considerable importance due to their predation in gardens, orchards, nurseries, greenhouses, among others (Berg, 1994). According to Fuentes (2006), there is considerable damage to horticultural crops such as lettuce, zucchini, aubergine, cabbage, cauliflower, chard, green beans, broccoli, artichoke, carrots, beetroot, potatoes, garlic, strawberries, peaches, orchids, etc. Pests have also been recorded on beans, coffee, tobacco, bananas, Musaceae, flowers (chrysanthemums), and cuttings at ground level at germination, causing damage similar to that caused by cutworms (Thome, 1993; Maceira, 2003). According to Andrews (1987), it is reasonable to think of a loss of 15% to 20% of potential return caused by the effects of the Holocaust in Central America, thus estimating that the region loses between 27 and 45 million dollars per year.

In addition, for Lu et al. (2018), the parasites that some snails have may be lethal because they produce various stomach and brain conditions (Monge-Nájera, 1996; Maceira, 2003; Barrios and Fernández, 2004). According to Aguirre (2000) and Maceira (2003), some of these nematodes' parasites are the best known in our region, such as *Angiostrongylus costaricensis* (Morera and Céspedes, 1971) and *A. cantonensis* (Chen, 1935).

The distribution of these two species of the genus *Angiostrongylus* in the Americas is wide, with *A. costaricensis* mainly in Central and South America, and *A. cantonensis* in the Caribbean, Central and South America, and the United States, where they cause many diseases. In addition, both parasites have been identified in Panama (Kaminsky et al., 1987; Kaminsky, 1996; Valente et al., 2018). Both species of parasites cause neurological and abdominal angiostrongyliasis, and when their larvae accidentally parasitize humans, this is considered a zoonosis; however, in different American

countries, there are numerous reports of these diseases (Acha and Szyfres, 2003; Maldonado Jr. et al., 2010; Spratt, 2015).

Humans can contract these infections by consuming mollusks that are raw or undercooked and contain L3 larvae. These larvae migrate to the brain, where they develop to reach the L4 stage and then die. This reaction triggers severe neurological damage and can even be fatal (Graeff-Teixeira et al., 2009; Thiengo & Fernandez, 2013; Silva et al., 2022). In addition, human infection may occur accidentally when mollusks release nematode-infected mucus onto foods such as fruits and vegetables (Oliveira et al., 2010; Silva et al., 2022). In Brazil, *A. cantonensis* is considered an emerging zoonosis because it is the etiologic agent of eosinophilic meningitis (Morassutti et al., 2014; Ramos de Souza et al., 2018; Valente et al., 2020; Thiengo et al., 2022).

Some methods of propagation of land snails by humans are usually by cars, boat transport, by rail, through supplies used in the construction of houses and ornamental plants (Ascensão & Capinha, 2017); in addition, according to Michalak (2010) and Mienis and Rittner (2010) there are reports of land snails found in grains and vegetables traded by international markets and that are sometimes not detected due to the routine inspections that are carried out in some countries.

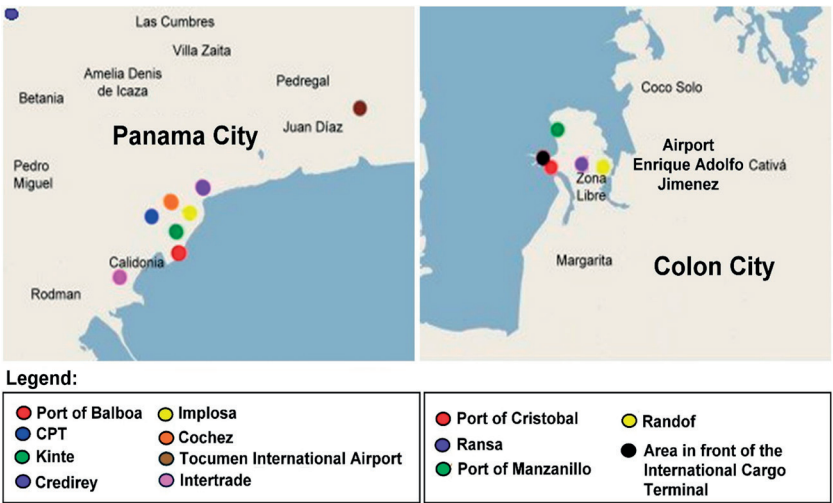
In South America, specifically in Brazil, Carvalho et al. (2012) in their research found mollusks infected with larvae of *A. cantonensis* in 11 ports; this parasite has also been identified in all regions of the world, except Europe and Antarctica; more than 2,800 cases of eosinophilic meningitis in humans attributable to this nematode have been reported in about 30 nations (Wang et al., 2008; Cowie, 2013; Kim et al., 2014). The bulk of reports on this condition, which is also known as rat lungworm disease, come from tropical and subtropical areas in Southeast Asia and the Pacific Rim. However, isolated cases have also been documented in other locations, including in regions where *A. cantonensis* is not present when individuals return from areas where it is found (Ramos de Sousa et al., 2018).

Despite the existence of important loading ports, no studies had been carried out in Panama until 2025 to identify the species of land snails found in products exported from other countries, which could potentially represent a danger to crops, animals, and the general population of our country. This situation led us to write this manuscript to identify and characterize important species of terrestrial, agricultural, and medical mollusks in the port areas of Panama, evaluating their diversity and epidemiological risk. This provided us with fundamental information on how to identify these species and implement suitable management and control measures.

MATERIAL AND METHODS

Location of the study area

We look for the main locations where planes, large ships, and trucks from Panama and around the world transport goods. We find these in Panama City and Colón, two important cities in the Republic of Panama (Figure 1 and Table 1).



Source of field data from 2009, edited by Stephanie Castillo

Figure 1: Maps of the geographical distribution of the sampling site in Panama City and in the city of Colón.

Field methodology

Samples were collected twice a week per month, in the dry season (January to March 2008) and the rainy season (April to December 2008 and 2009), at the selected locations and in each cargo area or port. Four points were chosen where snails were thought to be due to their characteristics. To ensure samples were always taken at the same location, the Garmin® GPS device was used to locate the exact location of each collection point. The places where the samples were taken had different types of soil, such as wet leaf litter, rocks, and fallen logs, where land snails live. The collectors (four) sampled each point in the loading zones and ports for about 15 minutes, with one person at each collection point at each site, which equated to about 60 minutes (one hour) in total for the four points in each cargo zone or port.

Table 1: The location from where the samples of the study were collected, corresponding to the main logistics and cargo centers in Panama City and in the city of Colón.

Name of Entity/ Place	Category	Location (Coordinates)	Specialization and Key Services
Tocumen International Airport	Air/ Logistics	9°04'17"N, 79°23'01"O	Main airport of entry; Massive passenger and cargo handling with global connections. Located at the airport, international cargo transport and tugboat assistance in ports.
CPT (Tocumen)	Air/ Logistics	9°04'55"N, 79°22'46"O	National parcel services and distribution of construction and hardware products. Importing and selling plumbing and electrical supplies; home delivery and pickup services.
Cochez Logistics Center	Land/Commercial	9°04'14"N, 79°25'12"O	Pacific Side of the Canal; Leading center for container transshipment and sea freight.
Implosa	Land/Commercial	9°01'03.1"N, 79°29'01.3"O	
Port of Balboa (PPC))	Maritime (Pacific)	8°57'27"N, 79°33'40"O	

InterTrans / Intertrade	Logistics/ Land	Near the Panama Canal	Storage, container handling, and local distribution with dry and refrigerated trucks.
Kinte	Logistics/ Land	North Corridor (Mile 8) / Panama City	Specialists in the storage and handling of containers in strategic areas.
Port of Cristobal (PPC)	Maritime (Atlantic)	9°20'27"N, 79°53'31"O	Atlantic Entrance (Colón): historic port connected to the Colon Free Zone.
Manzanillo International Terminal (MIT)	Maritime (Atlantic)	9°21'43"N, 79°52'56"O	World-class logistics center; leader in transshipment for Central America and the Caribbean.
Randof y Ransa	Free Trade Zone/ Warehouse	9°21'35"N, 79°54'02"O	Located in Colón, comprehensive storage and distribution services within the logistics complex.
Credirey	Provincial/ Colón	9°2'3.9"N, 79°27'27.5"O	Company registered with the Colón Chamber of Commerce; logistics operations in the province.

Laboratory Methodology

Dry materials (empty shells) and living material were collected, which, according to Calvo (1994) recommends putting the living material in containers filled with water for 12 hours and then introducing them in alcohol with a concentration of 70%. All individuals were taken to the Research Building of the University of Panama, where they were labeled with the following information: name of the project; code assigned with the name of the location; date and species of the collection; day, month, and year of the collection; name of the species, author, and family; location and type of sampling. Part of the species identification was done by Dr. David Robinson, who works for Animal and Plant Health Inspection Service (APHIS), which is part of the U.S. Department of Agriculture (USDA). Snail samples were identified by observing their shells, their different shapes, patterns, and features that can be seen, and compared with specimens from a field guide for the recognition of terrestrial mollusk species (Morales & Carrillo, 2000; Robinson, 2010).

Data analysis

Diversity indices were used to determine the species richness of each area with respect to others, and a comparison was made between the areas of both provinces (Krebs, 1972; Newman et al., 2003).

We used the Simpson index (D') to see how much more common one species is than others and how diverse it is in a habitat. The value ranges from 1 to 0, where 1 indicates that one or two species dominate and 0 indicates that no species dominates and is used to show how much one or two species are more common than others in a community. We also used the Shannon-Wiener index (H') to compare how diverse a group of organisms is. This is based on the number of species (n) and the number of individuals (ni) of each species. Data were complemented with the Equity Index (Pielou) which is a way of seeing how equally organisms are distributed among the different types of living beings, the value shows how many individuals of each species there are in the population, this goes 0 to 1, where 1 means that all individuals are of the same species and 0 means that no individual is of the same species (Krebs, 1972).

RESULTS

Over the course of a year, we managed to successfully gather a total of 2,481 snails representing seven distinct species in nine genera and four families in Panama and Colón. The presence of *Allopeas gracile* (Hutton, 1834) was confirmed in 10 cargo areas, 1,566 individuals (66.12 %) were collected, most of them were at the Tocumen International Airport in the Pacific ($n= 482$; 19.43 %) and Puerto Cristóbal in the Caribbean ($n= 330$; 13.30 %) (Table 2).

Table 2. Number of individuals per species found in each of the sampling sites during period sampling.

Sampling Locations	Species Found				Total	
	Genera and Species		Genera	Family		
Tocumen International Airport	<i>Allopeas gracile</i>	482	73	---	56	690
	<i>Bulimulus unicolor</i>	3	---	---	---	103
	<i>Diplosolenodes occidentals</i>	12	5	---	---	13
	<i>Leptinaria unilamellata</i>	1	---	---	---	185
	<i>concentrica</i>	---	---	---	---	198
	<i>Sarasinula plebeia</i>	---	---	---	---	182
	<i>*Praticolella mexicana</i>	---	---	---	---	4
	<i>Subulina octona</i>	---	---	---	---	1
	<i>T. decolorata</i>	---	---	---	---	---
	<i>Succinea</i> sp.	---	---	---	---	---
Port of Balboa		49	3	12	32	6
	Cochez	1	---	---	5	---
	CPT	152	22	---	---	---
	Credirey	145	2	---	41	---
	Implosa	175	---	---	6	---
Intertrade		---	---	---	1	---
		---	---	---	---	4

Kinte	34	2	---	13	---	4	---	--	57	---	110
Area in front of the International	---	---	--	--	--	--	48	---	---	--	48
Cargo Terminal											
Port of Cristobal	330	6	--	---	31	---	5	---	17	---	389
Puerto de Manzanillo	177	2	---	---	5	---	171	---	138	---	493
Free Zone (Randof and Ransa)	22	--	---	---	---	---	13	---	32	---	66
Total	1,566	110	17	14	37	12	246	12	404	62	2,481

*First record of the presence of this species in Panama.

In addition other species were collected such as *Bulimulus unicolor* (G.B.Sowerby I, 1833) ($n=110$; 4.43 %), *Diplosolenodes occidentalis* (Guilding, 1824) ($n=17$; 0.68 %), *Leptinaria unilamellata concentrica* (Reeve, 1849) ($n=14$; 0.56%), Physidae Fitzinger, 1833 ($n=62$; 2.50%), *Praticolella mexicana* Perez, 2011 ($n=37$; 1.49%), *Sarasinula plebeia* (P. Fischer, 1868) ($n=12$; 0.48%), *Subulina octona* (Bruguière, 1789) ($n=246$; 9.91%), *Succinea* sp. ($n=404$; 16.28 %) and *Tamayoa decolorata* (Drouët, 1859) ($n=12$; 0.48 %); these land snails were recorded and collected predominantly during the rainy season, where they were very active reproductively, being *A. gracile* the most frequent species in both seasons, but in the rainy season its quantity increased abruptly, both in 2018 ($n=538$; 21.68 %) and in 2019 ($n=934$; 40.22 %), compared to the dry season ($n=101$; 4.35 %) (Table 3).

Table 3. Number of species collected and relative abundance during the dry and rainy seasons.

Species	Dry Season	Rainy Season		Total
	2009	2008	2009	
<i>Allopeas gracile</i>	101	538	934	1,472
<i>Bulimulus unicolor</i>	10	38	67	105
<i>Diplosolenodes occidentalis</i>	7	17	3	20
<i>Tamayoa decolorata</i>	0	2	0	2
<i>Leptinaria unilamellata concéntrica</i>	0	14	0	14
Physidae	0	56	6	62
<i>Praticolella mexicana</i>	0	13	23	36
<i>Sarasinula plebeia</i>	0	12	0	12
<i>Subulina octona</i>	0	74	176	250
<i>Succinea</i> sp.	28	114	235	349
Total	146	878	1,444	2,322

It should be noted that *P. mexicana* is reported for the first time in Panama and is recognized as a significant agricultural pest in other regions; we also recorded a total of 434 specimens that were only categorized at the genus or family level; due to insufficient morphological data, these were 404 specimens of the genus *Succinea* and 62 individuals of the family Physidae and among all the individuals collected, 3% were slugs, while snails accounted for 97%.

Another aspect to mention is that the presence of these specimens was linked to international cargo containers handled by private individuals; where we observed a decrease in the richness and abundance of species during

periods of high temperature and low humidity, typical of the dry season, some specimens were also found buried several centimeters underground, which were activated with the arrival of the rainy season.

An analysis of biodiversity across the sampling locations in the provinces of Panama and Colón revealed no distinct advantage for any specific type. Both provinces likely represent moderately favorable environments ($H' = 1.00$), and a moderate distribution of abundance ($J' = 0.50$) was noted; species numbers were relatively equal, as indicated by values close to one (Table 4).

Table 4. Diversity indices of terrestrial molluscan species by city.

Places	Diversity Indices		
	Simpson Indices (D')	Shannon-Wiener Indices (H')	Equitability Indices (J')
Panama	0.7259	1.579	0.7583
Colón	0.5963	1.043	0.7511
Total	0.8368	2.038	0.8191

DISCUSSION

The analysis recorded a total of 2,481 continental mollusks distributed in seven families, identifying eight species and one genus. Species *Allopeas gracile* (Hutton, 1834) was the most common in this research, being found in all sites sampled during the dry and rainy seasons of 2008 and the rainy season of 2009. According to Robinson (2010), this species is considered a pest due to its rapid reproduction rate and high consumption. Its distribution covers the tropical and subtropical regions of Asia, Australia, and Polynesia, as well as parts of Central and South America (Capinera, 2017). Although its exact origin remains unknown, Capinera (2017) suggests it originated in South America. Santos et al. (2010) highlights that it is a synanthropic species capable of surviving in habitats with lower humidity, similar to other synanthropic subulinids. It is presumed to have arrived in Panama by maritime transport, along with various plants or fruits.

The study identified a variety of snail species, with the most common belonging to the family Subulinidae (1,826 specimens), followed by Succineidae (404 individuals). *Succinea* sp. was very frequent across all the places studied, thriving in humid areas near water, which supports the statement of Monge-Nájera (1996) that they can inhabit both terrestrial and aquatic environments. Morales & Carrillo (2000) identified three species of *Succinea*, the second most common group in this study, in Nicaragua. This suggests that these species could have migrated to Panama from other regions, as they were sampled at multiple locations. Snails in this family can easily spread through

various plant materials. Mollusks thrived due to favorable environmental conditions, as noted by Morales & Carrillo (2000), who reported a preference for high humidity.

The third most common species was *Subulina octona* (Bruguère, 1789), which is found in the port of Manzanillo. This species has been intercepted in regions of Africa, Asia, and the Americas, indicating its wide distribution. Quirós et al. (2024) highlight its importance in any country in which it lives, as it can carry two types of worms that pose risks to human health.

Diplosolenodes occidentalis (Guilding, 1824) and *Sarasinula plebeia* (Fischer, 1868) are detrimental to crops such as beans, posing challenges for farmers and agricultural inspectors (Saunders et al., 1998). According to Aguirre (2000), these snails also serve as hosts for *Angiostrongylus costarricensis* (Morera & Céspedes, 1971). The *S. plebeia* species has the potential to cause significant agricultural damage in Central America, with farmers suffering considerable economic losses. In addition, it is likely that *S. plebeia* is present in Panama, having arrived with numerous non-native plants and animals.

The identification of *Praticolella mexicana* Perez, 2011, known for its destructive effect on crops, represents its first record in Panama, as indicated by Quirós et al. (2024). Notably, *P. mexicana* was observed more frequently in Colón than in Panama, where it was only recorded once, while multiple sightings were made in Colón. This snail is a known pest of papaya (*Carica papaya*), some fruits can seriously damage and according to Perez (2011) these snails have several of the characteristics common to invasive species, such as the ability to inhabit high densities within shrubs, tall grasses, and among waste. They are often seen climbing walls and grass. Still, they generally inhabit terrestrial environments, frequently associated with open areas or important shrublands due to their role as agricultural pests and as potential vectors of parasitic nematodes (such as *Angiostrongylus*) that affect humans and animals.

The Panama City airport recorded the highest number of land snails among the five species studied, totaling 690 individuals, while Puerto Escondido had the lowest abundance with a single specimen of the same species. The Port of Manzanillo had the highest count in Colón, with 493 individuals of the five species examined. Robinson (personal communication) noted that ceramic products from Italy could serve as transport vectors for snails, as these materials create an ideal, moist environment for mollusks.

The specific types of snails present in Panama remain largely unknown. However, one species, *Physa acuta* (Draparnaud, 1805), of the Physidae family, was frequently found in areas with high humidity, especially near rainfed rivers, and is known to carry a parasitic worm that can affect human health; in addition, Robinson (2010) indicates that Panama is home to

several snails that could not be detailed in this study, since some inhabit the soil and often carry pathogens, such as *A. cantonensis* (Chen, 1935).

Some species present in cargo areas and ports were already naturally home to nematodes *A. cantonensis* and *A. costaricensis*, which are responsible for causing eosinophilic meningitis and/or abdominal angiostrongyliasis, respectively (Ohlweiler et al. 2010, Morassutti et al. 2014), including *S. octona* (infected by *A. cantonensis*) (Ohlweiler et al. 2010, Ramos de Souza et al. 2018).

Families such as Physidae, Succineidae, and Veronicellidae have been documented in Central America, the Caribbean, and adjacent regions; a separate study in Colombia indicated that invasive species may have originated in Europe (Hausdorf, 2002). This suggests that species from other continents could also inhabit Panama, although the magnitude of this remains unclear due to the scant knowledge about local snails prior to this research; including data on the possible detection in our country of *Achatina fulica* (Férussac, 1821), which is not mentioned in this study, but has been reported in several regions of the world, including Brazil, where its presence is notable. It is classified as an urban pest (Thiengo et al., 2007). In addition, it has been linked to the proliferation of eosinophilic meningitis in Brazil (Morassutti et al., 2014; Thiengo and Fernández, 2016). The most dangerous aspect of this is the movement of containers and goods through ports of entry, which complicates accurate tracking of species introduction.

Burch (1960) and Iannacone (2006) indicate that shipments of agricultural products from regions such as Europe and the Pacific Islands (Hawaii, Tahiti, Micronesia, Guam, Rota, etc.) can harbor snails, which can pose significant threats to agriculture by hindering cultivation and trade. Robinson (2010) emphasizes the importance of these organisms in the transmission of diseases that affect other organisms, including humans and animals. Shipments of grains and fruits from Central American countries such as Costa Rica, Honduras, and El Salvador, where these snails are present, pose a potential risk to our country.

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CONFLICT OF INTEREST

There is no conflict of interest to disclose.

USE OF THE ARTIFICIAL INTELLIGENCE

No artificial intelligence tools were used in this study.

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