BABOSAS TERRESTRE (MOLLUSCA: GASTROPODA) EN LAS ZONAS INTERNACIONALES DE CARGA Y DESCARGA DE PANAMÁ

LAND SNAILS AND SLUGS (MOLLUSCA: GASTROPODA) IN THE INTERNATIONAL LOADING AND UNLOADING AREAS OF PANAMA

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Resumen: Este estudio tiene como objetivo identificar las especies de caracoles y babosas terrestres que podrían invadir Panamá a través de los sitios de carga y descarga de mercancías nacionales e internacionales en la Ciudad de Panamá y Colón, junto con sus probables lugares de origen. La investigación también considera los impactos ecológicos, económicos y de salud de estas posibles especies invasoras. Entre septiembre de 2008 y septiembre de 2009, se realizó muestreo en los principales puertos marítimos y aeropuertos de la Ciudad de Panamá y Colón, incluyendo sus contenedores, almacenes y hábitats naturales circundantes. El estudio utilizó GPS para marcar las ubicaciones con precisión, y el muestreo se llevó a cabo dos veces por semana. Se recolectaron especímenes, con material vivo fijado en alcoholal 70%, y se diseccionaron babosas para la identificación a través de órganos sexuales. La identificación taxonómica involucró características conquiológicas y consulta experta, con los datos analizados para correlacionar la abundancia de especies con la precipitación y la humedad. Se recolectaron un total de 2379 individuos, identificando siete especies en nueve géneros y cuatro familias taxonómicas, siendo la familia Subulinidae la más abundante. Notablemente, *Praticolella griseola*, una plaga agrícola, y *Hapiella w. f. decolorata* fueron nuevos registros para Panamá. El estudio encontró que la riqueza y abundancia de especies se correlacionaba con la lluvia, pero no con la humedad relativa. La investigación destacó la importancia de cuarentena de varias especies debido a sus roles como plagas y vectores de enfermedades como *Angiostrongylus cantonensis* y *A. costarricensis*. Panamá alberga una diversidad ecológica moderada de gasterópodos, con ciertas especies que representan riesgos significativos para la agricultura, la salud pública y los ecosistemas nativos. El estudio subraya la necesidad de vigilancia y manejo continuos de las introducciones de moluscos no nativos, particularmente en un centro de comercio global como Panamá. Identificar y comprender la distribución de gasterópodos invasores es

crucial para desarrollar medidas de control efectivas y mitigar su impacto en el medio ambiente y la salud humana.

Palabras clave: Gasterópodos, especies invasora, Puerto de Balbo, Puerto de Manzanillo, babosas.

Abstract: This study aims to identify the species of land snails and slugs that may invade Panama through the loading and unloading sites of national and international merchandise in Panama City and Colon, along with their probable places of origin. The investigation also considers the ecological, economic, and health impacts of these potential invasive species. Between September 2008 and September 2009, sampling was conducted at the main seaports and airports of Panama City and Colon, including their containers, warehouses, and surrounding natural habitats. The study utilized GPS for accurate location marking, and sampling occurred twice a week. Specimens were collected, with live material fixed in 70% alcohol, and slugs dissected for identification through sexual organs. Taxonomic identification involved conchological characteristics and expert consultation, with the data analyzed for species abundance correlation with precipitation and humidity. A total of 2379 individuals were collected, identifying seven species across nine genera and four taxonomic families, with the Subulinidae family being the most abundant. Notably, Praticolella griseola, an agricultural pest, and Hapiella w. f. decolorata were new records for Panama. The study found species richness and abundance correlated with rainfall but not relative humidity. The research highlighted the quarantine importance of several species due to their roles as pests and vectors of diseases like Angiostrongylus cantonensis and A. costarricensis. Panama hosts a moderate ecological diversity of gastropods, with certain species posing significant risks to agriculture, public health, and native ecosystems. The study underscores the necessity for ongoing surveillance and management of non-native mollusk introductions, particularly in a global trade hub like Panama. Identifying and understanding the distribution of invasive gastropods are crucial for developing effective control measures and mitigating their impact on the environment and human health.

Keywords: Gastropods, invasive species, Port of Balboa, Port of Manzanillo, slugs.

INTRODUCTION

Gastropods belonging to the phylum Mollusca have about 100,000 described species and potentially 100,000 species yet to be described (Strong *et al.* 2008). The influence of direct or indirect human-caused dispersal of terrestrial gastropods should be taken into consideration when interpreting the capacity or extent of species to modify their range. Transport constitutes more than 90% of the unintentional introductions of foreign species (Roques *et al.* 2009). The human introduction of some species of gastropods by ship, car, or train transport with plants, soil, or building material seems to be the most important method of spreading (Ascensão & Capinha 2017).There are many reports of gastropods speciesinadvertently incorporated into shipments of plant materials in international trading, and exported grain shipments have been rejected due to snail contamination (Michalak 2010; Mienis & Rittner2010).

The impact of invasive species on ecosystems is enormous and might go beyond damage to biodiversity. Since exotic species have evolved in a different environment, they may have a new predation behavior with novel weapons or new properties that may alter the functioning of the new ecosystem. Invasions of exotic species often involve significant economic losses and severe health problems, which makes them a direct threat to human well-being (*Aguirre et al. 2009*). Worldwide, 39% of known extinctions of local animals have been caused by the introduction of foreign species (Pérez-Bedmar & Pérez 2003). Some snails, especially carnivorous species, can affect the indigenous land snail fauna and may rapidly exterminate local species in some cases.

An indirect damage that might be caused by mollusks is due to the transmission of parasites and pathogens to humans and the rejection of exports due to contamination of products. Land slugs and snails are involved in the transmission of bacteria such as *Salmonella* (Monge- Nájera 2003) and parasites causing angiostrongyliasis, clonorchiasis, fascioliasis, fasciolopsiasis, opisthorchiasis, paragonimiasis and schistosomiasis (Lu *et al.* 2018). Nematodes found in some of these terrestrial mollusks are *Angiostrongylus costarrisensis* (Morera 1987) and A. cantonensis (Maceira 2003) which cause intestinal angiostrongyliasis and eosinophilic meningoencephalitis (brain disease) that can lead to death. The nemato de *A. costarrisensis* has been reported for the American continent in several countries including Panama causing these diseases (Valente *et al.* 2018).

The economic risks of alien mollusks in Panama might be caused by feeding damage and contamination of crops with their feces and mucus. In Central America economic losses caused by mollusks range from 15-20% of potential yield, which is equivalent to $27-45 million dollars per year (Andrews & Dundee 1987). Slugs and snails damage a wide variety of crops, mainly vegetables and legumes (Thome 1993; Maceira 2003). Land mollusks are vulnerable to dehydration because their skin is highly permeable and because they move by laying down a band of moist mucus (Moreno-Rueda *et al.* 2009). The environmental factor is classified as the major cause that supports the life of Gastropoda because of the low migration capabilities. The most recent studies of the relationship between the distribution and abundance of terrestrial slugs and snails and environmental conditions are those of Nunes & Santos (2012) and the published data on land snails of Panama is limited or focuses on taxonomy with scarce ecological studies.

Despite the existence of important ports of entry, no studies have been conducted in Panama to identify species arriving at ports from other regions that may pose a risk to crops as well as human and animal health. Therefore, the purpose of this work was to determine the species of land snails and slugs that may invade the country through the sites of loading and unloading of national and international merchandise in Panama City and Colon and their probable place of origin.

MATERIAL AND METHODS

Containers and warehouses at loading and unloading areas in the main seaports and airports of cities of Panama and Colon, as well as the surrounding area, were examined carefully during one year from September 2008 to September 2009. Sampling points were the followings:

1. Panama City: Tocumen International Airport, Balboa Port and backyards, containers, and warehouses of eight commercial companies that receive merchandise from these seas and airports.

2. Colon City: Cristobal and Manzanillo ports and two additional sampling sites (Colon Free Zone, International Loading Area).

Each area already mentioned was visited, choosing as collection points those that are the natural habitats of gastropods and had the necessary characteristics for the development of a gastropod population or a community such as humid soils with leaf litter or presence of rocks and fallen logs, inside the wooden pallets, near the channels, in the vegetation and near cement floors. Special care was given to places of transport and storage of ceramic containers, tiles, clay, and wood. The sampling points were established using a global positioning device (GPS) Magellan® brand, so that it would always sample the same place. Sites selected were those that would guarantee to obtain the highest number of samples. The sampling was done twice a week by three collectors surveying the area for 15 minutes, equivalent to 45 minutes per site approximately. Sampling was conducted for one year to determine the effect of the dry and rainy season on fluctuations in gastropod populations. Temperature, elevation, and relative humidity was recorded in each collection site. Monthly precipitation and environmental humidity were obtained from the Instituto Nacional de Estadística y Censo Panamá (2021).

Taxonomic determination of the collected material: Dry material (empty shells) and live material were collected. The living material was placed in containers covered with water for 12 hours and then fixed in 70% alcohol, as suggested by Calvo (1994). Slugs were dissected to identify them through their sexual organs. All the collected material was placed in the reference collection of the Laboratory of Biological Studies of Arthropods (LEBA-UP) located in the Gemelo Torre 1 of the University of Panama and in the Museum of the Smithsonian Institution in Washington, D.C, United States. Snail samples were identified using conquiological characters such as morphology of the shell, its structure, ornamentation, and some visible external characteristics (Morales & Carrillo 2000; Robinson 2010). Since distinguishing closely related species is difficult even for experts in the group and would be impossible without extensive training, most of the taxonomic determination was carried out with the collaboration of Dr. David Robinson from the Animal and Plant Health Inspection Service (APHIS), a section of the United States Department of Agriculture (USDA). Economic, ecological, and medical importance were determined by reviewing the literature and website, however detailed data for many species were unavailable. The abundance of species per month, precipitation, and relative humidity at the collection sites were plotted and a correlation analysis between precipitation and the abundance of mollusks per month was carried out using Microsoft Excel (2007).

RESULTS AND DISCUSSION

A total of 2379 individuals corresponding to seven species, nine genera and four taxonomic families were collected during one year in Panama and Colon ports (Table 1). The identified species were: *Allopeas gracile, Subulina octona, Bulimulus unicolor, Praticolella griseola, Diplosolenodes occidentales, Leptinaria unilamellata concéntrica and Sarasinula plebeia.* Six specimens of *Hapliella* were considered like *Hapliella decolorata*. A total of 434 individuals were identified at the genus or family level. A lack of anatomical data did not allow us

to determine the species of 375 specimens of *Succinea* and 54 individuals of the Physidae family. The species *Praticolella griseola*, which is considered an important agricultural pest in other countries, is a new report for Panama. Of the total number of individuals collected, only 3% were represented by slugs, while 97% were snails.

Species collected belong to Subclass Heterobranchia and Superorder Eupulmonata. There were three orders represented: Stylommatophora (five families, seven species), Systellomatophora (one family, two species) and Basomathophora (one family). The most species-rich family and the most abundant as well was Subulinidae (three species and 73% of all specimens).

Table 1 shows that the number of species found in Panama City was greater than in the Province of Colon. It is likely that this situation is due to the presence of more appropriate habitats in terms of humidity and vegetation in these collection sites. The sampling sites in the Province of Colon were characterized as open areas with lower humidity, making them unsuitable for slug and snail survival. The species *A. gracile* made up 61% of the total individuals collected followed by *Succinea* sp. (15%) and *S. octona* (11%). The remaining 13% of the specimens collected belong to seven species of land slugs and snails (Fig. 1).

Effect of relative humidity

The richness of land snail and slug species was higher in Panama City (eight species) while in Colon City only five species were collected. The species *Praticolella (Praticolella) griseola*, which is considered an important agricultural pest in other countries, is a new report for Panama and was collected around the Cristobal and Manzanillo ports in Colon City. There was no previous report in Panama of *Hapiella w. f. decolorata* that was found around three commercial companies in Panama City. These two species made up only 1.76% of the specimens in this study.

The total abundance of slug and snail species together was found to correlate with rainfall but not with relative humidity. The abundance of specimens by month increased with increasing precipitation ($R^2 = 0.86$, $P = 0.05$, Figs 2, 3, 4). Despite the low correlation, Fig. 4 shows that the abundance of specimens of the three more common species (A. gracile, S. octona and Succinea sp) increased with increasing relative humidity ($R^2 = 0.034$, $P = 0.05$).

Table 1

List of mollusk species and number of individuals collected in four sampling locations around ports of Panama and Colon City

SPECIES FOUND IN THE SAMPLING LOCATIONS OF COLON CITY

	Cristobal Port	Manzanillo Port	International Loading Area	Colon Free Zone
	A. gracile	*A. gracile*	---	*A. gracile*
	B. unicolor	*B. unicolor*	---	---
	P. griseola	*P. griseola*	---	---
	S. octona	*S. octona*	*S. octona*	*S. octona*
	Succinea sp.	*Succinea sp.*	---	*Succinea sp.*
Number of individuals	372	527	45	51
Number of species	5	5	1	3

Abbreviations: **TIA**: Tocumen International Airport; **BP**: Balboa Port; **MP**: manzanillo Port; **CFZ**: Colon Free Zone; ILA:International Loading Area; **CP**: Cristobal Port).

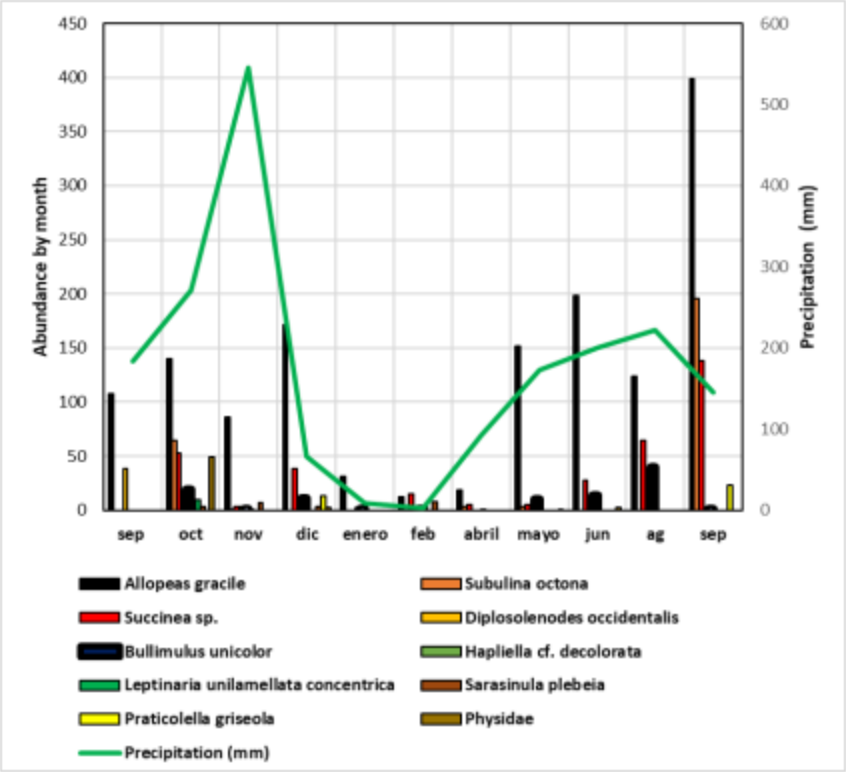

Figure 1

Monthly abundance of individuals per species and effect of rainfall during the year of study

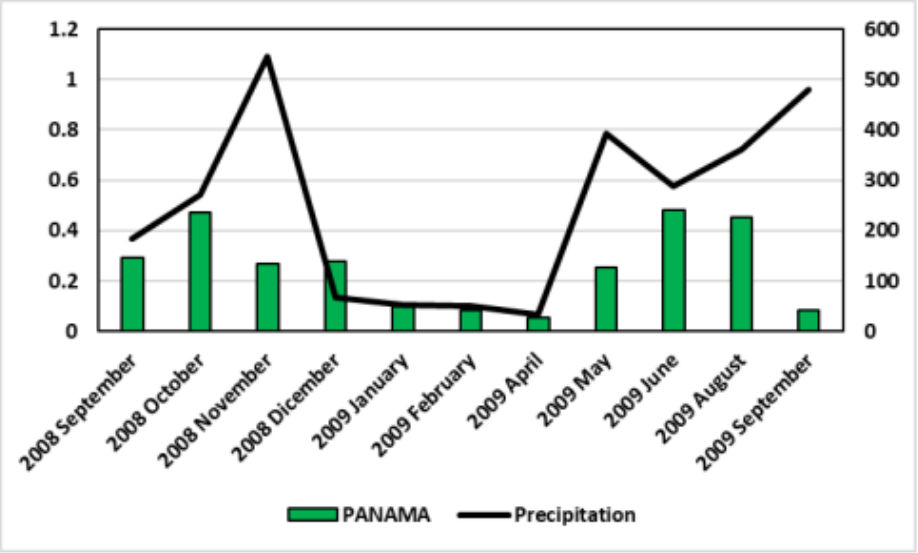

Figure 2

Effect of rainfall in the abundance of slugs and land snails by month in Panama City during the year

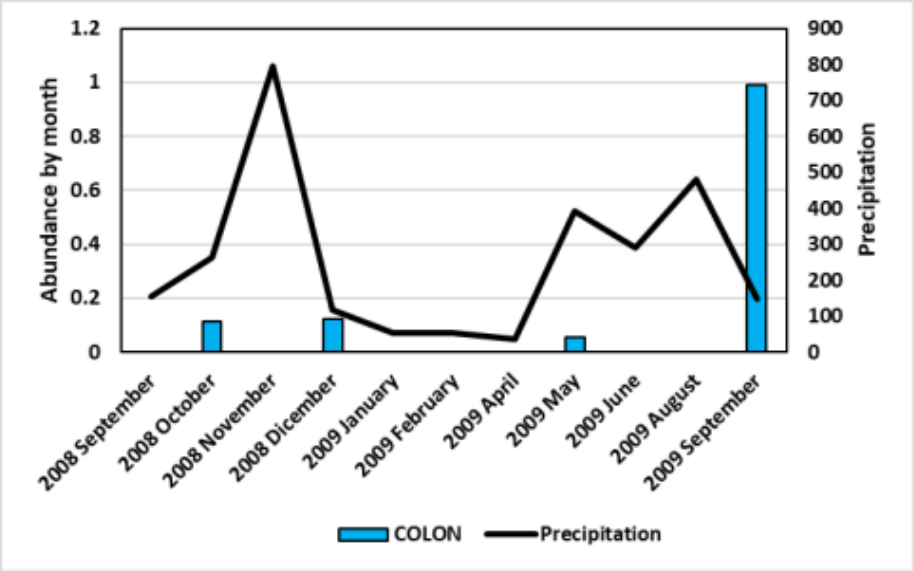

Figure 3

Effect of rainfall in the abundance of slugs and land snails by month in Colon City during the year

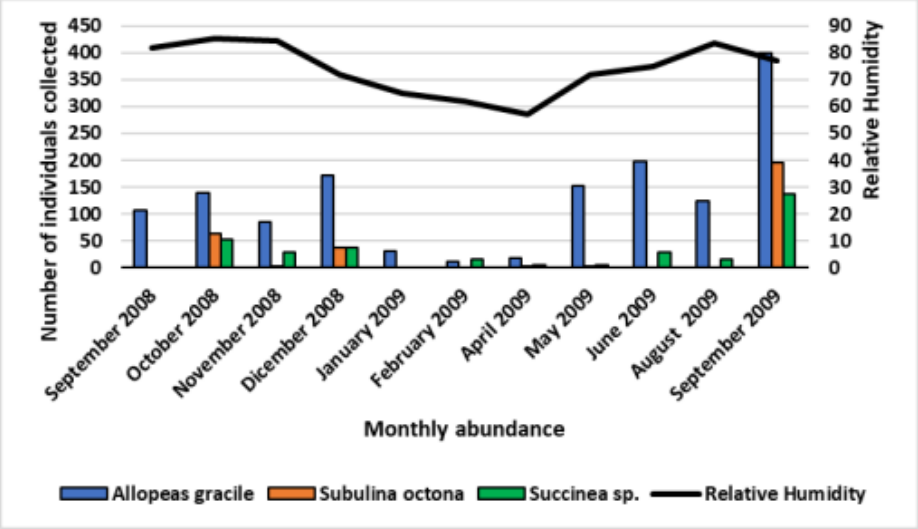

Figure 4

Number of individuals collected by month and the effect of relative humidity during the year of study

Seven species (five snail species and two slug species) were recorded in this study. The species *A. gracile* was the most abundant species in all the sites sampled during 2008 and 2009. According to Robinson (2010), this species is considered a pest because of its rapid reproduction and voracious appetite. This species is distributed from Southeast Asia to Central and South America so it has not been uncommon to find it in shipping sites in the Republic of Panama where it may have arrived in loads of plants or fruits. Although the

species of the genus *Succinea*, the second most important group due to its abundance in this study, could not be identified until species, Morales and Carrillo (2000), have reported three species already established in Nicaragua which may indicate that this group could have colonized (and perhaps established) in our country due to the abundance of individuals found at most sampling sites. Additionally, species of this family are associated with all types of plant material, which makes their dissemination even easier.

Subulina octona, a species that occupied the third place in abundance, was collected mostly in the Port of Manzanillo (89%), on the Panamanian Caribbean coast. This species has been intercepted in Africa, Asia, and the Americas, indicating that it is now widely distributed.

The presence of this species in any country is of great quarantine importance since it has been reported as a carrier of *Angiostrongylus cantonensis* and *A. costarricencis*. Although the species of the Family Physidae collected in Panama have not yet been identified to species, it is important to note that at least one species of this group: *Physa acuta* has been reported as a carrier of *Angiostrongylus cantonensis* (Robinson 2010). The species *Diplosolenodes occidentalis* and *Sarasinula plebeia* are extremely important from an agricultural-quarantine point of view as they are pests of beans and other agricultural products (Saunders *et al.* 1998). Additionally, they are established hosts of *Angiostrongylus costarricencis*. (Aguirre 2000). The species *Sarasinula plebeia* is of great agricultural importance in Central American countries, where economic losses ranging from 35 to 100 % have been reported (Rueda *et al.* 2002).

The most abundant family in this study was Subulinidae with 1741 individuals (73%), followed by *Succineidae* with 349 individuals. Succinea sp. was abundant in very humid places or near ponds, which is consistent with what was said by Monge-Nájera (2003), that it is an amphibious species. This species was found in almost all the places sampled. Physidae is the only freshwater family found in this study. It was associated with areas of high humidity, near tributaries of water produced by rainfall. Two species identified in this study, (*Praticolella (Praticolella)* griseola and *Hapiella w. f. decolorata* might be considered exotic species since they were recently introduced to Panama and therefore are of quarantine importance posing a threat to Panama's agriculture and public health. The species *P. griseola* was more abundant at the sampling sites of the Province of Colon, with only one individual found in the Province of Panama. This species is reported for the first time for the Republic of Panama and is of great quarantine importance because it is an aggressive pest of papaya (*Carica papaya*), an important fruit for Panamanian citizens (Robinson 2010).

The collection site with the highest abundance of individuals collected in the Province of Panama was the Tocumen International Airport with 622 individuals belonging to six species. In the Province of Colon, the site with the highest abundance of individuals was the Port of Manzanillo with 527 individuals belonging to five species. The type of cargo that represents a potential risk for the introduction of exotic species of snails and slugs, according to Robinson (personal communication), is that coming from Europe, specifically from Italy, where ceramic products are shipped since these might contain mollusks that are attracted by the humid environment of plastic packaging and wooden pallets. In addition, shipments of agricultural products from Europe, Pacific Rim islands (Hawaii, Tahiti, Micronesia, Guam, etc.) can harbor slugs and snails that await a favorable environment for reproduction (Birch 1960; Iannacone 2006). In all these countries, these mollusks have caused such large losses in agricultural production that export earnings from agricultural products have dropped considerably. On the other hand, it is important to note the great importance that these organisms have as transmitters of diseases to animals and humans (Robinson 2010). These mollusks are more abundant in the rainy season when they show their greatest activity and reproduction and all were found associated with international cargo containers, green areas, or scattered nearby garbage. The number of species and the abundance of individuals decreases due to high temperatures and low humidity during the dry season.

Perhaps these mollusks enter a process of estivation and possibly remain several centimeters underground until the end of the dry season. In contrast, during the rainy season, a significant increase in the number of species and abundance of individuals was observed at all sampling sites since humidity is an indispensable factor for the life of these organisms (Morales & Carrillo 2000)

An analysis of total diversity of all sampling sites in the provinces of Panama and Colon found that there is a moderate distribution of individuals per species (J'= 0.50), so there is a moderate ecological diversity (H' = 1.00). According to this study there is no clear predominance of one or more species despite the great abundance of individuals collected from *A. gracile* (D'= 0.52).

According to our registers in Panama, introduced land mollusks seldom invade natural wild environments. It seems that they stay limited to disturbed environments (Hausdorf 2002).

In this study were found families and species of snails and slugs (Physidae, Succineidae, Veronicellidae, P. griseola, A. gracile and S. octona), which are potentially transmitters of nematodes, parasites, bacteria, and viruses that can affect the health of humans and native animals. Most of the species registered have been reported before in Central America, Caribbean Islands, and the surrounding areas. In a similar study carried out in Colombia, the invasive species came from Europe (Hausdorf 2002). Perhaps species from other continents are already present in Panama but are not recorded because the taxonomy of snails is poorly known, and some species are difficult to distinguish. The origin of the exotic species of gastropods found in this study could not be determined with precision due to the unpredictable movement of containers and merchandise in the ports of entry that prevent the relationship between the collected individuals and the country of origin. With the results obtained in the quantitative analysis of ecological diversity, it has been found that Panama has a relatively high ecological diversity of these mollusks and there is not yet a considerable predominance of any species for this region.

Unfortunately, there is no information about the time of introduction of the non-native snails and how many species have arrived since Panama emerged from the ocean to become a Mesoamerican bridge approximately 20 million years ago (O'Dea *et al.* 2016). Nowadays, because of the geographic position of Panama and the increasing global trade, it is possible that the process of the introduction of alien mollusks is continuing. To be able to take appropriate control measures we must keep surveying new introductions and analyze the real distribution and impact of already established non-native land mollusks.

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