

FIRST RECORD OF *TOMOSTELE MUSAECOLA* (MORELET, 1860) (GASTROPODA: EUPULMONATA: STREPTAXIDAE) FROM THE DOMINICAN REPUBLIC AND ITS CURRENT DISTRIBUTION IN THE WESTERN HEMISPHERE

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ABSTRACT: The presence of alien mollusc species in an ecosystem has a negative impact on the endemic mollusc fauna and can result in economic losses. The West African land snail *Tomostele musaecola* (Morelet) was previously recorded from numerous localities in the Western Hemisphere. In this paper, we provide a new locality of this malacophagous snail in the Dominican Republic. The species is recorded from an urban park named Parque Ecológico Las Caobas in the province of San Cristóbal. In order to update the current distribution of *T. musaecola* in the Americas we examined the literature and the online database of the Invertebrate Zoology Collection of the Florida Museum of Natural History (FLMNH); when available, citizen science data were also used. A map is provided to illustrate the current distribution of the species in the Americas. The total number of records in the Western Hemisphere is 51, and 26 of them are part of this review. More studies are needed on the interaction of this species with the native land snails. Trade and planting of ornamental species in urban parks facilitate the establishment and expansion of alien molluscs.

KEY WORDS: alien species; hunter snail; range expansion; urban park; urban malacofauna

INTRODUCTION

Many species have been established in and introduced into new habitats due to inadvertent actions or deliberate human activities that frequently lead to ecological and economic damage (VITOUSEK et al. 1997). These non-native species affect the dynamics of biological communities, ecological processes, economy and human health; they may cause displacement or extinction of native species, resource competition, and spread of pathogens, especially on islands (CHARLES & DUKES 2008). Molluscs are no exception among the introduced taxa. Among land snails, carnivorous species of the family Streptaxidae have been introduced throughout the tropics and

subtropics. This has several implications for some native mollusc faunas (VAN BRUGGEN 1975, STANISIC 1981, NAGGS 1989).

Gulella bicolor (Hutton, 1834) and *Tomostele musaecola* (Morelet, 1860) are distinctive introduced streptaxids, also known as “hunter snails”. They have been introduced circumtropically into the Caribbean Basin, south-eastern United States of America, northern part of South America, São Tomé and Príncipe, Australia, Melanesia, Micronesia and Polynesia (AUFFENBERG & STANGE 2001, COWIE 2001, HAUSDORF & MEDINA BERMÚDEZ 2003, ROBINSON et al. 2009, BRODIE & BARKER 2012a,

GERBER & CLARK 2015, MIQUEL & HERRERA 2019, HOLYOAK et al. 2020). *G. bicolor* is a known predator of small invertebrates; it has been reported to feed on subulinid and pupillid snails and earthworms (MEAD 1961, DUNDEE & BAERWALD 1984, AUFFENBERG & STANGE 2001, BRODIE & BARKER 2012a).

T. musaecola is a small, non-operculated snail whose shell, with 8.75 whorls in total, is elongated (height up to 6.7 mm), imperforated, crystalline to whitish, with a narrow apex and similar diameter of mid-spire and body whorl. The protoconch is smooth while the teleoconch surface is covered with prominent radial ribs. The aperture is almost trapezoidal and its palatal lip is thickened and arched forward without apertural barriers. Its fairly concave columella has an oblique truncation at the base, the parietal callus is thick (PILSBRY 1930, SOLEM 1989, MIQUEL & HERRERA 2019). The body colour is translucent white with hints of pale green.

This carnivorous snail originally comes from West Africa. The species was first recorded in the Western Hemisphere at Port of Spain in Trinidad as *Luntia insignis* E. A. Smith, 1898 which was much later synonymised with *Streptostele* (*Tomostele*) *musaecola* (Morelet, 1860) by HAUSDORF & MEDINA BERMÚDEZ (2003). Recently HOLYOAK et al. (2020) raised the

subgenus to the generic rank, based on the comparison of the columella truncation and shell size of Príncipe Island taxa and *T. musaecola*.

In the following years, as a result of human activities, it was inadvertently introduced to other countries of the Western Hemisphere and was recorded from 25 localities in Central and South America, and in the Caribbean (HAUSDORF & MEDINA BERMÚDEZ 2003, ROBINSON et al. 2009, GERBER & CLARK 2015). It is known that *T. musaecola* is malacophagous, and it is supposed that its introduction to islands such as American Samoa has had a profound impact on native snails, leading to the extinction of indigenous species (COWIE 1998, HAUSDORF & MEDINA BERMÚDEZ 2003). The threat *T. musaecola* poses to native molluscs is still undocumented in other territories where it has been introduced (ROBINSON et al. 2009, BRODIE & BARKER 2012b, DELANNOYE et al. 2015, GERBER & CLARK 2015).

Here, we present data on a new record of *T. musaecola* in the Dominican Republic and update the information on the distribution presented by HAUSDORF & MEDINA BERMÚDEZ (2003), ROBINSON et al. (2009) and GERBER & CLARK (2015) for the Western Hemisphere, extending the distribution range.

MATERIAL AND METHODS

STUDY AREA

The study was carried out at Parque Ecológico Las Caobas, located in the province of San Cristóbal, Dominican Republic (18°25.00'N, 70°07.20'W; 88 m a.s.l.). This natural monument, 160,524 m² in area, is an urban park with many planted stands of *Swietenia mahagoni* (mahogany) and other native and exotic plant species (Figs 1, 2).

We selected an area with a mixture of trees, herbs and vines. The main tree species were *Albizia saman*, *Citrus* sp., *S. mahagoni*, *Mangifera indica*, *Melicoccus bijugatus* and *Guazuma ulmifolia*. *A. saman* and *S. mahagoni* were the major leaf litter contributors. Prominent patches of the exotic-invasive vine species *Antipogon leptopus* (coral vine) and *Centrosema* sp. covered the ground. Besides, herbs such as *Priva lappulacea*, *Spermacoce remota* and *Chamaesyce hirta* and a few fern species were present.

SAMPLING

Samples were taken during three field trips in February and April 2019 and October 2020, between 9:00 and 15:00. We selected one fixed transect, 100 m long and 2 m wide, where the average temperature and humidity were measured with a weather

meter (Kestrel 4500). Following SUÁREZ-TORRES & FERNÁNDEZ-VELÁZQUEZ's (2012) categories, an intensive search through all possible microhabitats was performed on each field trip in order to collect as many species and individuals as possible. An opportunistic collecting was also carried out outside the transect.

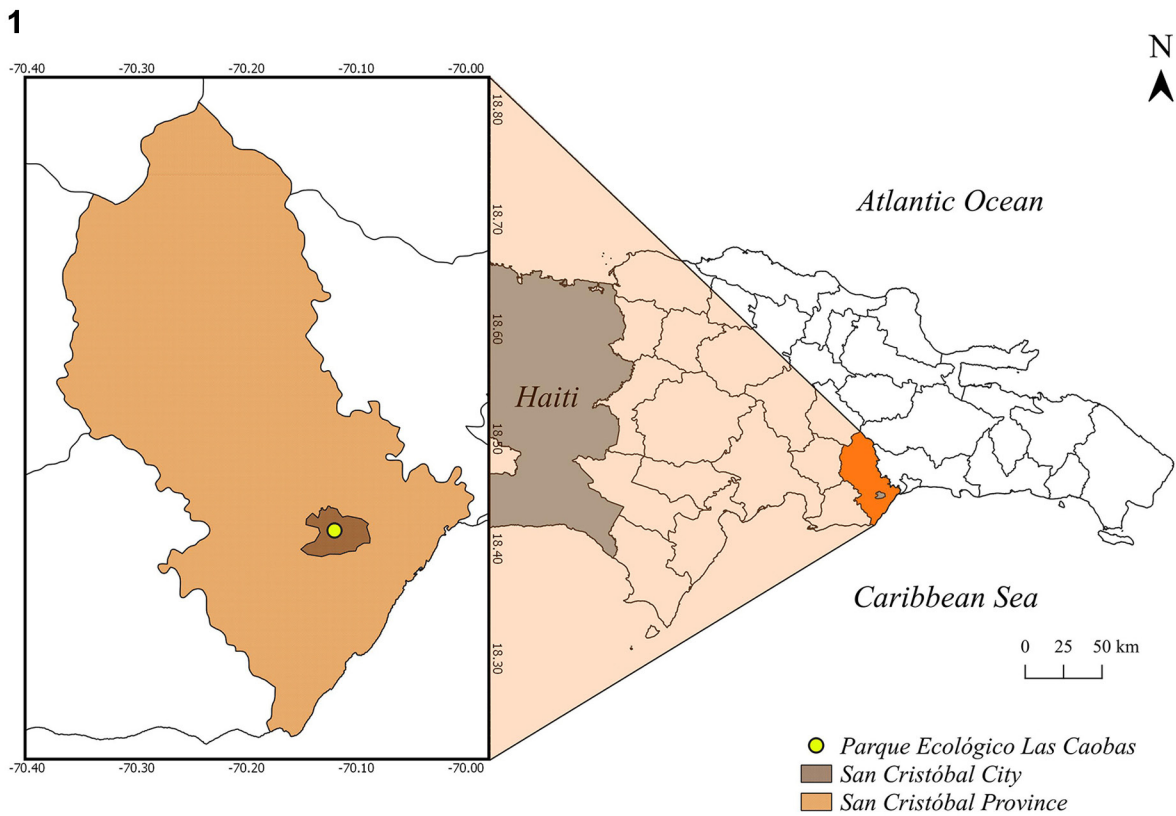
Large specimens of terrestrial gastropods were collected by eye. To collect minute shells and juveniles, leaf litter from different points within the transect was taken to the laboratory of the Instituto de Investigaciones Botánicas y Zoológicas Rafael M. Moscoso (IIBZ) where it was passed through sieves of different mesh sizes. All collected material was cleaned, labelled and deposited in the malacological collection of the IIBZ. Live specimens were relaxed by drowning them overnight in small containers with water and menthol crystals, and then preserved in a 70% ethanol solution. Measuring eyepiece was used for shell measurements of *T. musaecola*; we followed PILSBRY's (1930) criteria to distinguish adults from juveniles.

Species identification was based on the literature (TRYON & PILSBRY 1889, WAGNER 1907, VANATTA 1920, PILSBRY 1933, CLENCH 1962, SCHILEYKO 2006) and comparative specimens from the IIBZ malacological collection. The nomenclature of the species follows ESPINOSA & ROBINSON (2021).



The literature and the online database of the Invertebrate Zoology Collection of the Florida Museum of Natural History (FLMNH) were revised in order to add any records missing in the earlier reviews. Citizen science data (see Results) were used as proposed by VENDETTI et al. (2018) for updating

the information on the distribution of *T. musaecola* in the Americas. Coordinates were assigned to those records which had lacked them in the previous sources, following the instructions given by WIECZOREK et al. (2004) and MURPHY (2020). To prepare the maps, we used the open source program QGIS version 3.16.1.



Figs 1–2. Study area: 1 – location of the study area; 2 – wooded area of Parque Ecológico Las Caobas (area with high density of the exotic coral vine)

RESULTS

A total of 51 specimens of *T. musaecola* were collected. Only five of them (three adults and two juveniles) were found alive (Figs 3–8) beneath the litter, vines and herb mat, at the average temperature of 28.4 °C and humidity of 63.4%. The shell height of 46 of these specimens (26 adult and 20 juvenile) was measured. It ranged from 1.10 to 6.00 mm, with the mean of 4.10 mm. Adult shell height varied from 4.50 to 6.00 mm, with the mean of 5.39 mm, while juvenile shells ranged from 1.10 to 4.30 mm (mean 2.50 mm).

We recorded 609 individuals of 10 gastropod taxa and seven families which co-occurred with *T. musaecola* (Table 1). Two species could be identified only to the genus level due to their significantly damaged shells.

We documented 26 locality records for *T. musaecola* in the Western Hemisphere (18 from literature, four based on observations, two via personal communication, one occurrence in an online collection database, and the new locality recorded herein). Of these 26 locality records mentioned, 24 are insular and two continental (Fig. 9); they are added to the 25 reviewed by HAUSDORF & MEDINA BERMÚDEZ (2003), ROBINSON et al. (2009) and GERBER & CLARK (2015), which makes 51 occurrences in the Western Hemisphere known to date:

- Lesser Antilles. GUADELOUPE: Basse-Terre Island (16°08.96'N, 61°40.71'W), Grande-Terre Island (16°19.34'N, 61°25.58'W) and Marie-Galante Island (15°55.89'N, 61°16.14'W) (BERTRAND 2001, CHARLES 2015, 2016); Not specified (ANTUNES et al. 2018). MARTINIQUE: Morne Gras, Bellefontaine Commune (14°40.46'N, 61°08.81'W), Morne Caroline, Case-Pilote Commune (14°38.95'N, 61°07.41'W), Fond Moulin, Grand'Rivière Commune (14°52.47'N, 61°10.85'W), route forestière de Palourde, Gros-Morne Commune (14°42.16'N, 61°02.43'W), chemin forestier de la Propreté, Le Morne-Rouge Commune (14°45.54'N, 61°06.49'W), Anse Coulevre, Le Prêcheur Commune (14°50.56'N, 61°13.13'W), Morne Baldara, Le François Commune (14°34.66'N, 60°54.53'W) and Fontaine Notre-Dame, Le Vauclin Commune (14°32.72'N, 60°50.34'W) (DELANNOYE et al. 2015); observation by Delannoye in 2005 at Fort-de-France Commune (14°41.57'N, 61°05.77'W) (INVENTAIRE NATIONAL DU PATRIMOINE NATUREL 2019); observations by Gargominy in 2001 at De l'Anse Coulevre aux cascades du Mont Conil, Le Prêcheur Commune (14°51.39'N, 61°12.58'W) and Gargominy, Delannoye & Machon in 2011 at Presqu'île de la Caravelle, La Trinité Commune (14°45.27'N, 60°56.30'W) (INVENTAIRE NATIONAL DU PATRIMOINE NATUREL 2020).
- Greater Antilles. CUBA: Not specified (ESPINOSA et al. 1994, ESPINOSA & ORTEA 1999); All Cuban territory (PÉREZ et al. 1996); Instituto de Investigaciones de Pastos y Forrajes de Niña Bonita, Cangrejas, La Habana Province (23°02.33'N, 82°29.39'W) (CABRERA DÁVILA et al. 2004); Not specified (ROBINSON personal communication 2007); Sierra La Guasasa, Viñales, Pinar del Río Province (22°39.48'N, 83°42.43'W) (OLIVA-OLIVERA & REAL 2009); Occidental Region (MACEIRA et al. 2013). DOMINICAN REPUBLIC: Parque Ecológico Las Caobas, San Cristóbal, San Cristóbal Province (18°25.00'N, 70°07.20'W). PUERTO RICO: Not specified (ROBINSON personal communication 2007, ROBINSON & FIELDS 2014).
- South America. ECUADOR: Guayabillos, Santa Cruz Island, Galápagos Province (0°41.78'S,

Table 1. List of species co-occurring with *T. musaecola* in an area of 200 m² in Parque Ecológico Las Caobas, and the number of individuals recorded

Family	Species	No.	Alien/Endemic/Native
Achatinidae	<i>Subulina octona</i> (Bruguière, 1792)	1	Alien
Cepolidae	<i>Coryda monodonta</i> (Lea, 1831)	5	Endemic
Helicinidae	<i>Alcaldia succinea</i> (L. Pfeiffer, 1850)	215	Endemic
	<i>Fadyenia domingensis</i> (Vanatta, 1920)	164	Endemic
Oleacinidae	<i>Vagavarix</i> sp.	1	–
Sagdidae	<i>Hispaniolana undulata</i> (Férussac, 1821)	26	Endemic
	<i>Hojeda inaguensis</i> (Weinland, 1880)	157	Native
	<i>Lacteoluna selenina</i> (Gould, 1848)	3	Alien
Solaropsidae	<i>Caracolus</i> sp.	8	–
Thysanophoridae	<i>Lyroconus plagiptycha</i> (Shuttleworth, 1854)	29	Alien
	Number of individuals (total):	609	



90°20.78'W) (MIQUEL & HERRERA 2019). FRENCH GUIANA: observation by Ripken & Gargominy in 1999 at Parc Amazonien de Guyane à Saül, Saül Commune (3°37.32'N, 53°12.54'W) (INVENTAIRE NATIONAL DU PATRIMOINE NATUREL

2020). VENEZUELA: four specimens from the FLMNH (UF 383614) collected by Lionel & Miller in 1986 at Gruta De Lourdes, San Sebastián, Aragua State (9°57.36'N, 67°10.82'W) (PAULAY & BROWN 2020).



Figs 3–8. *Tomostele musaecola*: 3 – ventral view; 4 – lateral view; 5 – dorsal view; 6 – apex; 7 – base; 8 – live adult and juvenile individuals

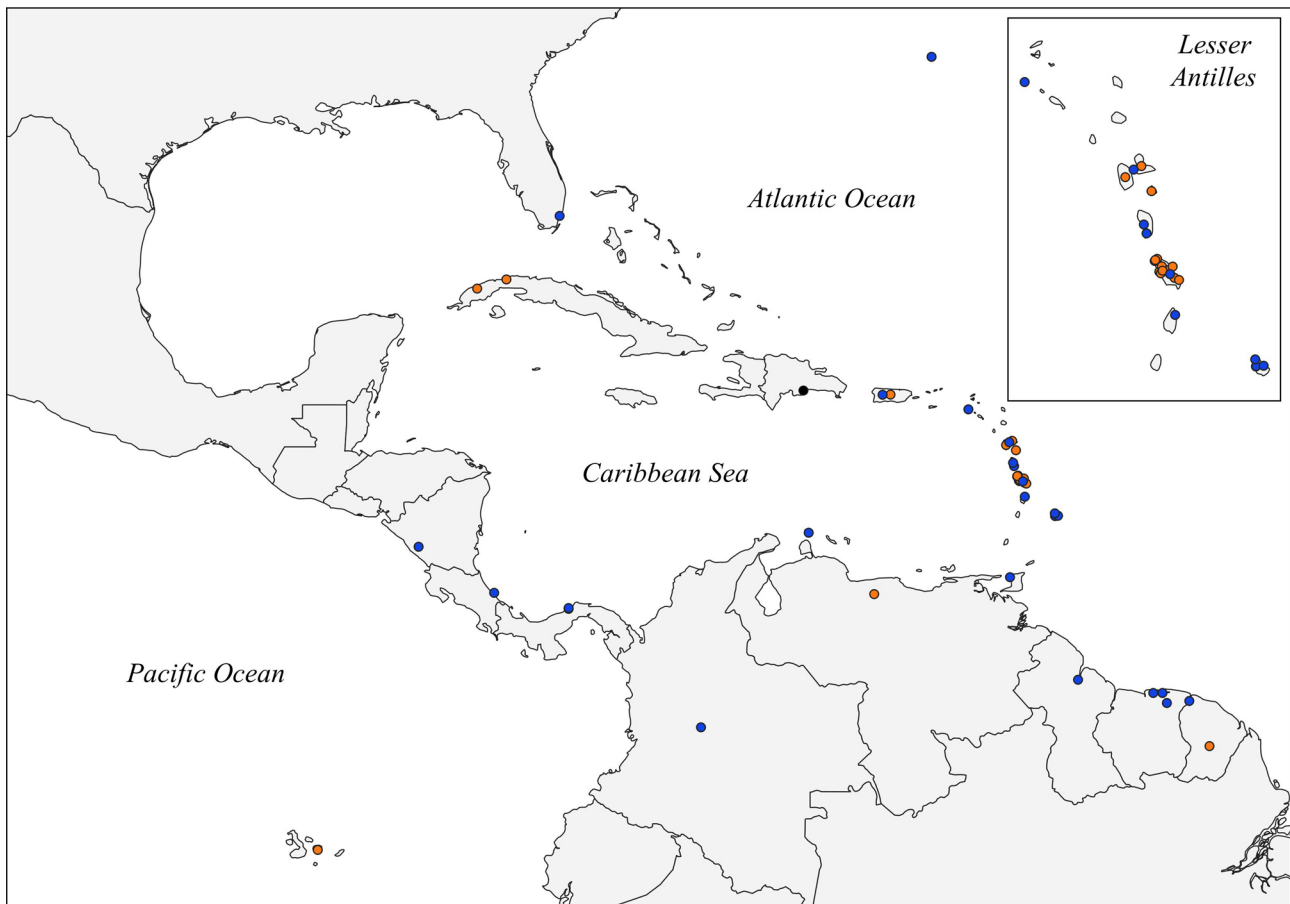


Fig. 9. Distribution of *Tomosteles musaecola* in the Western Hemisphere. Blue and orange dots represent localities reported by previous authors and added in this article, respectively. The new Hispaniolan locality is indicated in black

DISCUSSION

Tropical habitats of originally high biodiversity, which are much modified by human intervention, seem to facilitate the range expansion and establishment of fast-adapting alien species (PRENTIS *et al.* 2008, SAVITRI NURINSIYAH *et al.* 2016). *T. musaecola* may be one of such highly adaptable species (FONTAINE *et al.* 2007).

The introduction of *T. musaecola* in the Western Hemisphere dates from more than a century ago (SMITH 1898). Since then new localities within the Americas have been reported. These reports have only focused on providing new records, but with no information on the effects of this species on the native mollusc populations in the Americas. Publications by PILSBRY (1930), OLIVA-OLIVERA & REAL (2009) and GEBERT & CLARK (2015) provide compilations of data on *T. musaecola* and associated molluscs, but ecological data are limited to a minimum.

Fifty one localities of *T. musaecola* were reported from the American continent prior to 2020; 26 of those are reviewed here. These 26 occurrences include 11 localities overlooked (three from Guadeloupe, six from Cuba, one in Puerto Rico,

and one in Venezuela) in the previous reviews by HAUSDORF & MEDINA BERMÚDEZ (2003), ROBINSON *et al.* (2009) and GERBER & CLARK (2015), as well as 14 localities in our review (11 in Martinique, one in Guadeloupe, one in Ecuador, and one in a national park in French Guiana) which were added after 2015. The last occurrence corresponds to our new locality report (San Cristóbal, Dominican Republic).

The Cuban records of the snail date back to 1994 (ESPINOSA *et al.* 1994). *T. musaecola* was reported throughout the literature from a few Cuban localities. It was even suggested that it was distributed over the whole Cuban territory (PÉREZ *et al.* 1996), while other authors argued that its range on the island was restricted to the Western Region (MACEIRA *et al.* 2013). Our findings corroborate the data presented by MACEIRA *et al.* (2013), therefore the claim that *T. musaecola* is found throughout the whole Cuban territory is doubtful.

Despite the wide distribution in the Caribbean Basin, *T. musaecola* was not found on Jamaica and the Bahamas. Its introduction to these localities in the near future is plausible, due to the commercial and

touristic interchanges between the Caribbean Islands. No other records have been reported, apart from the previous ones, from other Central American countries. In South America the expansion continues. Peculiar situations are those in French Guiana, where the species occurs within a national park, and in the Galapagos where it is very likely to have been introduced from the equatorial continental zone (alternatively, it may have been introduced via Galapagos to continental Ecuador).

Anthropogenic disturbance presents a threat to micro-molluscs (DOUGLAS *et al.* 2013); many species have been introduced to these disturbed areas, increasing the risk of extinction of the native mollusc fauna. Some species of terrestrial molluscs, such as *Subulina octona* (Bruguière, 1792), *Bradybaena similaris* (Férussac, 1822) and *Deroceras leae* (Müller, 1774) (BRODIE & BARKER 2011, MACEIRA *et al.* 2013) are thought to be associated with anthropogenic transformations. OLIVA-OLIVERA & REAL (2009) regard *T. musaecola* as a potential indicator of anthropogenic and circum-anthropogenic changes. In Cuba, it has been reported to occur in secondary forests and lawns (ESPINOSA & ORTEA 1999, MACEIRA *et al.* 2013), and it has been found in disturbed areas in Puerto Rico and associated islands (ROBINSON & FIELDS 2014). On Fiji and other Pacific islands, this species has been recorded in disturbed lowland forests (BARKER *et al.* 2005, BRODIE & BARKER 2012a, b). Our new record of *T. musaecola* also comes from an anthropogenically transformed suburban area.

The introduction and invasion of ornamental plants in the natural vegetation cover bordering suburban environments, as well as deliberate planting, often lead to introduction and range expansion of alien molluscs in these areas. It is noteworthy that many species have been introduced as a result of commercial activities such as agriculture and horticulture (MEYERSON & MOONEY 2007). *T. musaecola* has been found associated with plantations of *Cocos nucifera* (coconut) (ROBINSON personal communication 2007) and *Theobroma cacao* (cocoa) (OKE & OMOREGIE 2012), and supposedly introduced via importations of banana (*Musa × paradisiaca*) (PILSBRY 1930). GEBERT & CLARK (2015) also suggest that the introduction of *T. musaecola* to Florida may have been due to trade in horticultural products. It is also worth mentioning that our study area is mainly covered by mahogany plantations and stands of other planted trees.

MORELET (1860) described *T. musaecola* from Guinea, apparently inhabiting the trunks of Musaceae. Nevertheless, the syntypes from the Natural History Museum (NHMUK 1893.2.4.276-278), collected by Morelet himself and figured by BREURE *et al.* (2018), originate from Gabon (Figs 10–11). GERBER & CLARK (2015) proposed, tentatively, an extension

of the native range of the species from Guinea to the Congo; however, *T. musaecola* might not be native to all areas in western-central Africa. According to OKE & OMOREGIE (2012), the species was recorded in Nigerian cocoa plantations, but they provide no information on whether *T. musaecola* was native or alien in this west African country. HOLYOAK *et al.* (2020) recorded the species from the islands of São Tomé and Príncipe, included it in introduced species of these islands, and restricted the type locality of the species to Gabon, based on BREURE *et al.* (2018). The native range of the species seems to be uncertain.

Urban parks in the Dominican Republic have variable levels of protection, where many of them are isolated and used for recreation. These parks contribute to the studies of biodiversity monitoring and survival of indigenous species, and are habitats for native and alien species. In many cases, the introduction of species is due to incorporation of materials, furniture and plants used for the aesthetical pleasing and adequacy of these green areas; it constitutes a direct or indirect danger to autochthonous species. Hypothetically, we propose that *T. musaecola*, along with the other introduced land snails species, was established in the study area by these scenarios.

Hispaniola is one of the least malacologically explored islands in the Caribbean Basin. This situation has led to a lack of knowledge regarding an approx-



Figs 10–11. *Achatina musaecola* Morelet, 1860: 10 – syntype NHMUK 1893.2.4.276, 5.9 mm; 11 – label of *A. musaecola* (NHMUK 1893.2.4.276-278). Modified from BREURE *et al.* (2018)

imation of faunistic richness and the ecological role of molluscs in its habitats. Minute land snails are the main undiscovered group from the Hispaniolan malacofauna, and the introduction of malacophagous land snails such as *T. musaecola* represents a risk to these poorly explored autochthonous species.

Among 660 specimens collected in the study area, *T. musaecola* represent 8% of the total number. The presence of *T. musaecola* could act as a pressure over the remaining carnivorous species in the study area (*Vagavarix* sp.), because of its higher density in comparison to that of the oleacinid. Due to the low numbers of specimens of *Subulina octona* and *Lacteoluna senelina*, previously reported as being associated with *T. musaecola* (OLIVA-OLIVERA & REAL 2009, DELANNOYE et al. 2015), we could infer that *T. musaecola* might be feeding on individuals of *Alcacia succinea*, *Fadyenia domingensis*, *Hojeda inaguensis* and *Lyroconus plagioptycha*. This might be particularly dangerous as two of these are endemic to the island. These are simple non-empirical scenarios as no concrete observations on these situations were performed.

Although the predatory behaviour of *T. musaecola* is known, its role in the extinction of the native mollusc fauna in regions where it has been introduced, has not been documented. More studies are needed on the interaction of this species with native land snail species.

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