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Author(s)	Lago-Barcia, Domingo; González-López, José Rafael; Fernández-Álvarez, Fernando Ángel
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The invasive land flatworm *Obama nungara* (Platyhelminthes: Geoplanidae) reaches a natural environment in the oceanic island of São Miguel (Açores)

DOMINGO LAGO-BARCIA^{1,2}, JOSÉ RAFAEL GONZÁLEZ-LÓPEZ³& FERNANDO ÁNGEL FERNÁNDEZ-ÁLVAREZ^{4,5}¹ Laboratório de Ecologia e Evolução, Escola de Artes, Ciências e Humanidades (EACH), Universidade de São Paulo (USP), Av. Arlindo Bettio, 1000, São Paulo, SP, 03828-000, Brazil<https://orcid.org/0000-0002-1852-4959>² Departamento de Zoologia, Instituto de Biociências da Universidade de São Paulo (USP), São Paulo, SP, Brazil³ Citizen scientist, retired high school teacher of Biology.<https://orcid.org/0000-0002-9660-3265>⁴ Ryan Institute and School of Natural Sciences, National University of Ireland Galway, University Rd., Galway, Ireland, H91 TK33.<https://orcid.org/0000-0002-8679-7377>⁵ Corresponding author: f.a.fernandez.alvarez@gmail.com

During an entomological sampling trip in the island of São Miguel (Açores, Portugal) on 02-11-2019 by José Rafael González-López, one specimen of the invasive flatworm *Obama nungara* Carbayo *et al.* 2016 was found under a rock (Fig. 1A). The specimen was photographed *in situ* and identified by its external morphology based on its large and broad leaf-like body with nearly parallel body margins, narrow and rounded anterior end, rounded posterior end, and dorsal pigmentation consisting of a light brown ground color covered with dark longitudinal and irregular stripes, and ventral surface grayish-white. Recent studies (Justine *et al.* 2020; Negrete *et al.* 2020) showed the reliability of photograph-based identification of *O. nungara* specimens. It is the sixth island where this species has been found (after Guernsey, Great Britain, Ireland, Corsica, and Madeira).

The site where the animal was found is a mount area named *Pico de Barrosa* at 947 meters of altitude (Fig. 1B). It is part of the mountain chain which surrounds a volcanic flooded caldera named *Lagoa do fogo*, which was classified as part of the Red Natura 2000 by the European Commission on 28-12-2001 under the terms of the Directive 92/43/CEE. This protected area is characterized by dense coverage of endemic vegetation, mainly composed by low scrubland and prairies in the southern hillside of the mount, illustrating its high ecological value. The specimen was found near the highest point of the reserve near the road EN5-2A and close to old buildings (coordinates: 37.760866, -25.492071).

Obama nungara was first recorded as an exotic land planarian in Europe in various localities of France (Justine *et al.* 2014a), Spain and England (Álvarez-Presas *et al.* 2014) but without a specific identification. Later on, Lago-Barcia *et al.* (2015) identified Spanish and Argentinean specimens as *Obama marmorata* (Schultze & Müller, 1857). However, Carbayo *et al.* (2016) studied specimens from Europe and Brazil and assigned the species spreading across Europe to the new species: *O. nungara*. The same year, Aldred (2016) provided a new record of the species in Oxfordshire, United Kingdom, in a plant pot coming from the Netherlands. Lago-Barcia *et al.* (2019) extended the European distribution of *O. nungara* to Portugal and other regions of Spain (Figure 1C). Molecular data (Lago-Barcia *et al.* 2019) showed that this species is formed by three different clades and while one of these clades is restricted to Brazil, the other ones are found in Europe. This study also identified Argentina as the country of origin of the two invasive clades found in Europe. Soors *et al.* (2019) identified specimens of *O. nungara* in Belgium. Their molecular data showed that the specimens from Belgium are members of the main clade spreading across Europe. Recently, Justine *et al.* (2020) performed a molecular study with a large number of individuals collected in France, reaching the same conclusions of Lago-Barcia *et al.* (2019) about the Argentinean origin of the European specimens.

So far, most of the *O. nungara* records outside its native range are from urban areas, gardens and greenhouses (e.g., Lago-Barcia *et al.* 2015, 2019; Soors *et al.* 2019, Justine *et al.* 2020; Negrete *et al.* 2020). The single exception is the record from L'Albufera (Spain), where this invasive land flatworm has been recorded in a natural ecosystem with high ecological, conservation and social values (The Local 2019). It is noteworthy that the most comprehensive study on the distribution of *O. nungara* across mainland Europe showed that the 500 meters of altitude level could represent an eco-

logical barrier to the dispersal of this species (Justine *et al.* 2020). However, the new record from Açores is well above this altitude level.

Biological invasions have become one of the main concerns for biodiversity conservation (Lowe *et al.* 2000). Native preys of exotic carnivores commonly have not developed any type of defense against the new invader, while new colonizers usually are devoid of natural predators in the invaded environments. This is especially true in geographically and evolutionary isolated environments, such as oceanic islands. Island ecological equilibrium has been extensively disrupted in the last centuries by human activities, such as the introduction animal species (e.g., rats and goats) as well as the effects of the international plant trade, representing important threats to these sensitive areas (Russell *et al.* 2017).

Taking into account that the international plant commerce has been reported as one of the main causes of invasive land flatworm dispersion (e.g., Aldred 2016), the absence of allochthonous vegetal species in the spot where the *O. nungara* specimen was discovered is intriguing. Although invasive *O. nungara* populations in Europe seem to be persistent and capable of surviving different climatic conditions and temperatures (Sluys 2016; Soors *et al.* 2019; Justine *et al.* 2020; Negrete *et al.* 2020), so far, the presence of this species in non-disturbed natural environments is still limited (The Local 2019; this study). The possible source of dispersion of this species into the natural area of São Miguel might be through the machinery which transported the building materials for the buildings found in the area, or the fact that several visitors frequent the area to enjoy the impressive views of the lake. Any of these mechanisms could have transported cocoons, immature and small individuals into the area, without noticing. This evidences the key importance of maintaining an adequate level of cleaning and sterilization of construction machinery that operates both in urban and natural environments, as well as the clothes and footwear of responsible tourists visiting high value natural areas.

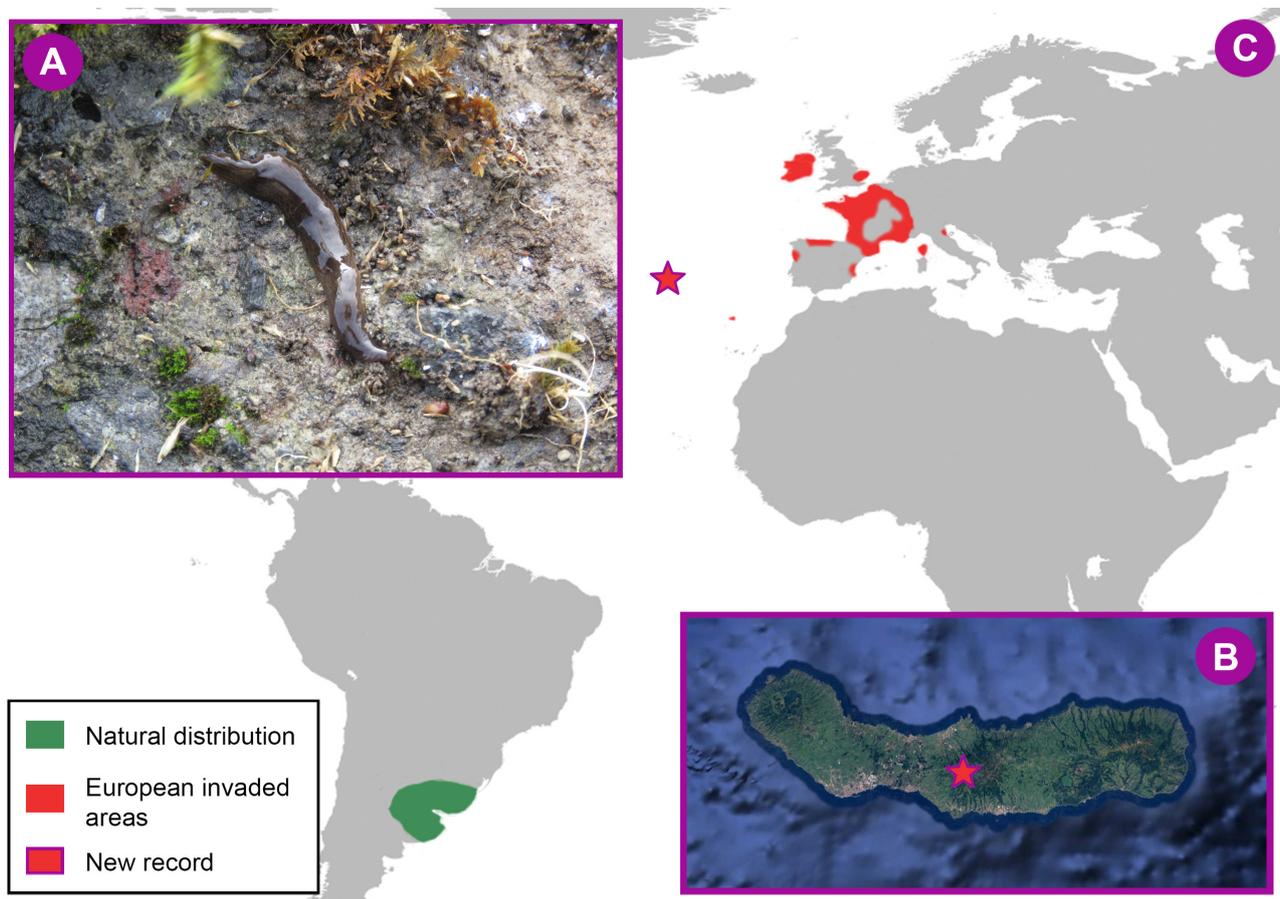


FIGURE 1. A. The invasive land planarian *Obama nungara* recorded in São Miguel Island (Açores) the 02-11-2019. B. The red and violet star signals the point of the record on São Miguel Island where the specimen was photographed. C. Global distribution of *O. nungara*; the native area (green) is based on records of Carbayo *et al.* (2016) and Lago-Barcia *et al.* (2015, 2019), the invaded area (red) is based in records of Álvarez-Presas *et al.* (2014), Carbayo *et al.* (2016), Justine *et al.* (2020), Lago-Barcia *et al.* (2015, 2019), Soors *et al.* (2019) and The Local (2019); the distribution in Ireland is based in the non-specific record of Justine *et al.* (2020: Table 2); the red and violet star signal the position of the new record in a global scale.

Obama nungara represents a new addition to this large group of alien flatworm species and a new concern for conservation in this area. As Boll & Leal-Zanchet (2016) showed, this species is a very efficient predator of diverse components of the soil fauna, such as gastropods, earthworms and other planarians. Soil fauna is a keystone component to ensuring the well-functioning of organic matter decomposition, nutrient recirculation and other ecological services provided by this important ecosystem (Coleman & Wall 2015). It has been shown that other invasive land planarians can produce huge effects on other soil fauna members, leading to species local extinction (e.g., Justine et al. 2014b) or even wider ecological damages, such as the ability of the soil to retain water in a particular area (e.g., Haria *et al.* 1998). Therefore, the early detection, monitoring and control of new invasive soil predators is extremely important to reduce important ecological cascade effects, especially in delicate and evolutionary isolated environments such as oceanic islands. Thus, the find of *O. nungara* in this natural environment should be taken into account by the authorities before it is too late.

Summary

We report a new finding of the invasive land flatworm *Obama nungara* Carbayo *et al.*, 2016 in a natural reserve of the oceanic island of São Miguel (Açores, Portugal) at 947 meters of altitude. This is the first record for this oceanic archipelago and the highest ever reported, representing the sixth island invaded by the species. *O. nungara* is a top predator of soil fauna, representing a new threat to the fauna of this isolated archipelago.

Conflict of Interest

The authors declare that they have no conflict of interest.

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