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FIRST RECORD OF THE NEW ZEALAND MUDSNAIL *POTAMOPYRGUS ANTIPODARUM* (J.E. GRAY, 1843) (TATEIDAE, MOLLUSCA) IN AFRICA

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ABSTRACT

Listed recently in the top ''hundred worst'' alien species and the third ''worst alien'' mollusc in Europe, the New Zealand mudsnail has become cosmopolitan. We report its first finding in the African continent, in Morocco. Established populations of *Potamopyrgus antipodarum* were found in the Low Moulouya wetland, a Ramsar and Biological and Ecological Interest Site (SIBE), occupying natural and anthropogenic habitats (spring, river and artificial canal). The invasion process seems to be in its early stages, calling for drastic measures to control its invasion progress.

Keywords: new arrival; Morocco; aquatic invasion; New Zealand mudsnail; alien gastropod.

RESUMEN

Primera cita en África del caracol del cieno de Nueva Zelanda *Potamopyrgus antipodarum* (J.E. Gray, 1843) (Tateidae, Mollusca)

Incluido recientemente entre las "cien peores" especies invasoras y siendo el tercero de los "peores moluscos invasores" en Europa, el caracol del cieno de Nueva Zelanda ha llegado a ser cosmopolita. Se comunica el primer hallazgo en el continente africano, en Marruecos. Se encontraron poblaciones establecidas de *Potamopyrgus antipodarum* en el humedal Low Moulouya, un Sitio Ramsar y un Sitio de Interés Biológico y Ecológico (SIBE), donde ocupa hábitats naturales y antropogénicos (manantial, río y canal artificial). El proceso de invasión parece estar en sus primeras etapas, lo que exige medidas drásticas para poder controlar su progreso.

Palabras clave: recién llegado; Marruecos; invasión acuática; caracol de barro de Nueva Zelanda; gasterópodo invasor.

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Introduction

The Maghrebian territory, located in the western and more arid part of the Mediterranean Basin, is recognized as a biodiversity hotspot (Myers *et al.,* 2000). Within the Maghreb, Morocco is particularly interesting for faunistic, ecological and biogeographical studies thanks to its geographical position; it represents a contact area between several regions, such as southern Europe and Africa. Its importance is associated with its role as a compulsory passage area for much of the fauna between the Palaearctic and Afrotropical regions.

The fauna of Morocco is characterized by a high rate of endemism (Taybi *et al.,* 2019; Mabrouki *et al.,* 2020a). The country has multiple geographical barriers, such as the Moulouya River Basin, the Sahara, the Rif Mountains and the Atlas Mountains. The latter divide the northern part of the country into two bioclimatic regions, which in turn are associated with high levels of endemism (Mabrouki *et al.,* 2019a). This high endemicity makes communities vulnerable to the arrival of new invasive species lacking a shared evolutionary history (Ellender *et al.,* 2015). Freshwater biodiversity and habitats are increasingly being affected by human activities worldwide, and freshwater ecosystems may well be the most endangered ecosystems in the world (Stiassny, 1999), particularly by biological invasions (Dukes & Mooney, 1999).

Invasive species are a major threat to global biodiversity, causing the decline and extinction of native aquatic species throughout the world (Strauss *et al.,* 2006). Growth in international trade and concurrent increases in transport capacity have accelerated the rate of introduction of alien species worldwide, with aquatic ecosystems and their native communities being particularly susceptible (Macdonald & Tonkin, 2008). Invasive species can be introduced into a new region through three broad mechanisms: the importation of a product, the arrival of a transport vector or natural spread from a neighbouring region where the alien species is already established (Mendoza *et al.,* 2014).

Within molluscs, many species have been considered as invasive in freshwater ecosystems (Karatayev *et al.,* 2009). They are represented mainly by Bivalvia, such as the Asian clam *Corbicula fluminea* (O.F. Müller, 1774) (Domagała *et al.,* 2004), and the zebra mussel *Dreissena polymorpha* (Pallas, 1771) (Reeders & de Vaate 1990), but also by Gastropoda, such as the apple snail *Pomacea canaliculata* (Lamarck, 1828) (Estebenet & Martín, 2002). Another good example of biological invasion success in phylum Gastropoda is the New Zealand mudsnail *Potamopyrgus antipodarum* (J.E. Gray, 1843), which is one of the most successful invasive freshwater mollusc species worldwide. It has invaded a wide variety of freshwater and estuarine habitats in all continents, except for Antarctica and Africa (Collado, 2014; Alonso *et al.,* 2019; Levri *et al.,* 2020).

In this paper, we report the first finding of established populations of the New Zealand mudsnail *Potamopyrgus antipodarum* in the African continent, in Morocco. We discuss possible mechanisms of introduction. Moreover, we aim to increase awareness on the impacts of invasive species on native fauna in Morocco.

Material and methods

Study area

The Moulouya River, with its length of almost 600 km, is one of the longest rivers of Morocco and the Maghreb. It is located in the northeast of the country and flows into the Mediterranean Sea. Its main permanent tributaries are the Ansegmir, Melloulou, Za and Msoun rivers. Other tributaries are currently intermittent (three to five flash floods on average per year) (Mabrouki *et al.,* 2019b; Taybi *et al.,* 2020a). The Site of Biological and Ecological Interest (SIBE) of the lower Moulouya extends over an area of almost 3000 ha, over a length of 25 km (Fig. 1). It presents various aquatic ecosystems, including the mouth of the Moulouya River and its floodplain, the coastal marine strip 6 km in length, the dune ridge, salt marshes with semi-temporary immersion and a river channel of 7 km length (Dakki *et al.,* 2003).

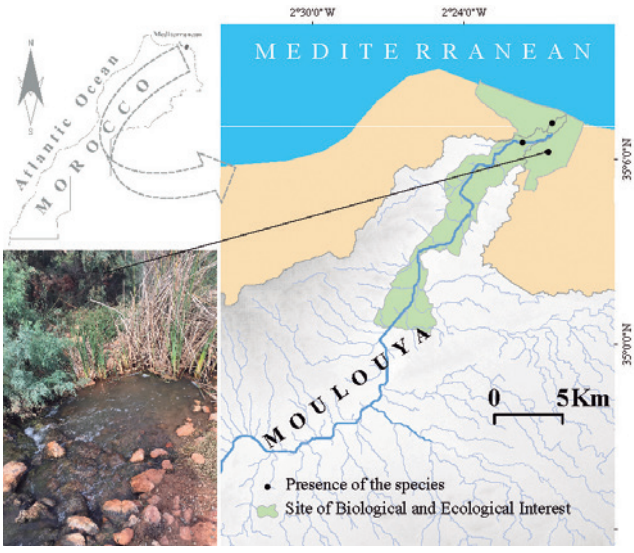

Fig. 1.— Map showing the location of the Ramsar site of the Moulouya wetland and the distribution area and habitat type (Chrarba spring) of *Potamopyrgus antipodarum* (J.E. Gray, 1843) in Morocco.

Fig. 1.— Ubicación del sitio Ramsar del humedal Moulouya, el área de distribución y el tipo de hábitat (manantial Chrarba) de *Potamopyrgus antipodarum* (J.E. Gray, 1843) en Marruecos.

Sampling

During field surveys conducted from 2014 to 2020, more than 100 localities were investigated in Eastern Morocco and the Moulouya River basin (see Mabrouki *et al.,* 2020a for additional details on localities). Most of these sampling sites were visited at least three times. The samples of benthic fauna including molluscs were collected with a Surber sampler (surface of 20 × 25 cm and 0.4 mm mesh net). Conductivity, pH, dissolved oxygen and temperature were measured *in situ* with a multiparametric measuring device (WTW, Multi-Line P4).

The measurements of the shells were carried out using a stereo microscope (ZEISS); the photographs were taken with a digital camera system (Leica R8). The map was made using ArcGIS software.

Fig. 2.— Habitus of *Potamopyrgus antipodarum* (J.E. Gray, 1843).

Fig. 2.— Hábitus de *Potamopyrgus antipodarum* (J.E. Gray, 1843).

Results

New Zealand mudsnails were detected in three locations of the >100 water bodies prospected (Fig. 1, Table 1), most of them brackish or moderately mineralized, near to the coast and always at low altitude. About 400 individuals have been collected (Fig. 2). We dissected eight specimens (all females). The habitats range between the spring of Chrarba, the potamal section of the Moulouya River and the artificial canal of Saidia; all these localities belong to the Ramsar site of the low Moulouya wetland. Our observations represent the first records of established populations of *P. antipodarum* in Morocco and in the African continent.

Discussion

The New Zealand mudsnail has successfully spread through fast rivers, slow-flowing and fresh, brackish and saline water ecosystems all around the world, including lakes, streams, and estuaries (Naser & Son, 2009). In some invaded areas, the densities of the species can exceed 500 000 m^2 (Hall *et al.,* 2006). The number of individuals of *P. antipodarum* collected was relatively low in this first study. This suggests the invasion could be in its initial stage. It is expected that the species range will increase exponentially across the five continents. In European waters the species has been present for more than 100 years, and its further expansion in temperate freshwater ecosystems is still ongoing (Rakauskas *et al.,* 2007; Butkus *et al.,* 2014), which is already noted in the neighbouring invaded areas. Alonso *et al*. (2019) have shown that the species has invaded the entire Iberian Peninsula and it is in a clear spreading phase, which makes its control very difficult, especially because of its non-water mediated dispersion mechanisms (e.g., mud or birds). This is the reason why it has been recently added to the top ''hundred worst'' alien species and the third ''worst alien'' mollusc (Nentwig *et al.,* 2018).

Table 1.— Records of *Potamopyrgus antipodarum* (J.E. Gray, 1843) in the Ramsar site of the Moulouya wetland. Localities, dates, GPS coordinates and habitats and physical-chemical parameters of the water are provided.

Tabla 1.— Registros de *Potamopyrgus antipodarum* (J.E. Gray, 1843) en el sitio Ramsar del humedal Moulouya. Se indican localidades, fechas, coordenadas GPS y hábitats y parámetros físico-químicos del agua.

Locality	Dates	GPS coordinates	Abundance per m^2	Habitat	pH	Temperature °C	Conductivity µs/cm	Dissolved oxygen mg/l	Depth cm	Water speed cm.s^{-1}	Type of substrat
Chrarba	30/07/18	35°06'18.7"N 2°20'45.0"W	250	spring	7.5	25	2030	8	50	25	mud
Pont Moulouya	16/06/19	35°06'32.6"N 2°21'41.9"W	20	River	7.2	26	4700	7.5	80	5	mud
Canal Saidia	16/06/19	35°06'20.6"N 2°20'42.4"W	140	Artificial canal	7.8	25	1950	7	40	25	mud

Several hypotheses regarding the introduction of *P. antipodarum* have been proposed; some of them suggest shipping, either in ballast waters or water tanks. Long/short distance transport means related to commercial movements of aquarium and ornamental fish and plant trade have been also reported. In addition to transport on mud, fishing tools or recreational vessels, the mud snails may also travel by hitchhiking on bird legs or even inside the gut of birds or fishes (Zaranko *et al.,* 1997; Alonso & Castro-Díez, 2008; DFO, 2011). Waterfowl may be the main vectors for inland spread in Northern Africa, since many routes of bird migration between Europe and Africa cross the Iberian Peninsula and Morocco (Perez-Tris & Santos, 2004; Alonso *et al.,* 2019).

The enormous worldwide invasion success of the species is attributed to several biological features, including opportunistic diet, high growth rates, high ability to escape from predators and other related behavioural traits, parthenogenetic reproduction, and high degree of tolerance to desiccation and a wide range of abiotic parameters (Koetsier, 2006; Rakauskas *et al.,* 2007; Adema *et al.,* 2009; Drown *et al.,* 2011; Levri *et al.,* 2020).

Alien and invasive species keep being recorded from the aquatic ecosystems of Morocco, leading to the formation of new communities of species with diverse interactions and unpredictable damages, especially in freshwater ecosystems including the Moulouya River basin (Mabrouki *et al.,* 2020b; Taybi & Mabrouki 2020; Taybi *et al.,* 2020b, 2020c). This unique ecosystem is home for a diverse array of animal and plant species, many of which are endemic, rare and vulnerable, including freshwater molluscs such as *Aghbalia aghbalensis* Glöer, Mabrouki & Taybi, 2020, *Islamia tifertiensis* Glöer, Mabrouki & Taybi, 2020; *Theodoxus numidicus* (Récluz, 1841) and *Unio foucauldianus* Pallary, 1936 (Taybi *et al.,* 2017; Glöer *et al.,* 2020; Mabrouki *et al.,* 2020c). In addition to habitat destruction and deterioration of the quality of surface waters currently occurring in Morocco (Mabrouki *et al.,* 2017; Taybi *et al.,* 2020d), global change may increase the chance of success of exotic species by reducing the fitness of local species in the new environment (Dukes & Mooney, 1999). Many of the Moroccan endemic species would see their regional distribution greatly reduced or may even disappear. Given the absence of rigorous international databases that track species in real time and huge research gaps for invasive species in Morocco, in particular, or in Africa in general, a comprehensive and thorough knowledge of the current invasive species distribution at country or continental scale is necessary to ensure their effective management.

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