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First record of *Melanoides tuberculata* in Rhodes, Greece: a new invader or a failed introduction?

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Abstract. We report the first record of the freshwater snail *Melanoides tuberculata* on Rhodes Island, Greece. Empty shells were recorded in 2017 and 2021, followed by the observation of two live individuals in 2022, possibly indicating short-term survival and at least one overwintering event. Subsequent surveys revealed only shells, suggesting a transient or unsuccessful introduction rather than an established population. Seasonal hydrological instability may limit persistence. Continued monitoring is recommended.

Key words. Aegean, alien, non-native species, freshwater gastropods, aquarium trade

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Introduction

The continuous expansion of international trade has resulted in a growing rate of biological invasions worldwide, with no indication that this trend will stabilize in the near future (Hulme 2009; Chown *et al.* 2016; Seebens *et al.* 2017). The translocation of organisms beyond their native ranges and their subsequent spread can negatively affect native biodiversity and ecosystem functioning, for example through competitive displacement (Bertolino *et al.* 2014), hybridization with indigenous taxa (van Riemsdijk *et al.* 2020), pathogen introduction and transmission (Kilpatrick *et al.* 2010), and alterations of food-web structure (David *et al.* 2017). In addition to ecological consequences, biological invasions may also pose risks to human health (Schindler *et al.* 2015) and generate substantial economic costs (Lovell *et al.* 2006). Management strategies for invasive alien species focus on prevention, eradication, and long-term control, with effectiveness largely dependent on the early detection of newly established populations (Eyre and Barbrook, 2021). The importance of early detection and rapid response is further emphasized in European Union Regulation No. 1143/2014.

Freshwater snails are among the most commonly kept invertebrates in home aquaria and play an important functional role by grazing on algae and organic detritus (Duggan 2002; Kwong *et al.* 2010). The rapid development of the aquarium trade and selective breeding have increased both the diversity and availability of freshwater molluscs worldwide (Coelho *et al.* 2012), while given their generally low environmental requirements and high reproductive capacity, aquarium snail populations may expand rapidly under favourable conditions (Livshits and Fishelson 1983).

The disposal or release of aquarium organisms represents a major pathway for the introduction of non-native freshwater species into the natural environment (Pointier *et al.* 1993; Miyahira *et al.* 2021; Kalaentzis *et al.* 2023). In Europe, several freshwater snails popular in the aquarium trade have subsequently been recorded in the wild, sometimes forming self-sustaining populations with potential ecological impacts (Cianfanelli *et al.* 2016; Vinarski, 2017). Thermophilic species such as *Melanoides tuberculata* (O.F. Müller, 1774) (Caenogastropoda: Thiaridae) initially often

colonise thermal waters and/or artificially heated reservoirs (Milenković and Gligorijević, 2012; Piechocki *et al.* 2020; Nekhaev *et al.* 2024). Recent climatic warming, particularly milder winters, may facilitate the survival of such species and their further spread.

Melanoides tuberculata is a parthenogenetic freshwater gastropod native to Africa and South Asia and one of the most widely traded snail species in the aquarium trade (Livshits and Fishelson 1983). Owing to its usually parthenogenetic, viviparous reproduction and broad ecological tolerance, it became a highly successful invader and has been reported from numerous regions outside its native range. *Melanoides tuberculata* has been introduced in several European countries, Austria, Cyprus, Czechia, France, Germany, United Kingdom, Hungary, Ireland, Italy, Latvia, Malta, Netherlands, Poland, Slovakia, Spain, Sweden (Cianfanelli *et al.* 2016), and more recently in Serbia (Milenković and Gligorijević 2012), Romania (Sîrbu and Benedek 2017), and Greece (Avrithis & Fischer 2022). Here, we report the first records of *M. tuberculata* from Rhodes, Greece.

Materials and Methods

Field observations of *Melanoides tuberculata* were carried out at Rodini Park and the Zephyros estuary in Rhodes (Greece) between 2021 and 2024, within the framework of freshwater habitat surveys. Shells were collected by hand from the substrate and shoreline deposits. In addition, specimens in the collection of the Hydrobiological Station of Rhodes (HSR) were examined.

Results

The oldest record of *Melanoides tuberculata* in the wild in Rhodes is a fresh shell, which was collected in the intertidal zone of the Zephyros estuary (36.4287°N, 028.2346°E; Fig. 1) on 31 March 2017 (HSR 646). Subsequently, empty shells of *M. tuberculata* were detected in two adjacent localities at Rodini Park (36.4268°N, 028.2188°E; 36.4259°N, 028.2181°E) upstream of the Zephyros estuary in February 2021 (HSR 580). Two alive individuals were observed in a nearby locality in a stream in Rodini Park (36.4262°N, 028.2185°E) together with *Melanopsis wagneri* J.R. Roth, 1839 (Caenogastropoda: Melanopsidae) in September 2022 (Fig. 2). No specimens were found during subsequent visits to the same site and nearby freshwater localities in the following years. However, numerous empty shells of *M. tuberculata* were encountered in November 2024 at the beach surrounding the Zephyros estuary, indicating that there could still be an extant population in the area.

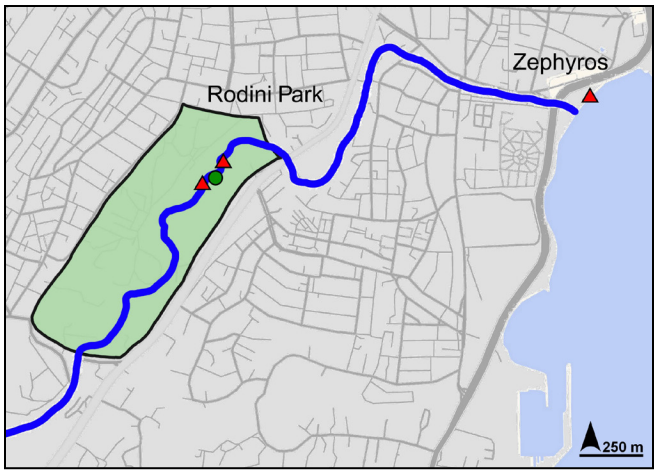

Figure 1. Occurrences of *Melanoides tuberculata* in Rhodes, showing Rodini Park and the course of the stream (blue line) flowing eastwards to the Zephyros estuary. Red triangles indicate localities where *M. tuberculata* shells were recorded, while the green circle marks the site where live individuals were observed.

Figure 2. Two living individuals of *Melanoides tuberculata* in the stream of Rodini Park along with *Melanopsis wagneri.*

Discussion

The discovery of *Melanoides tuberculata* in the intertidal zone of the Zephyros estuary in Rhodes in 2017 represents the earliest record of the species in Greece, predating the occurrence on Kos (Avrithis and Fischer 2022). There are no large natural wetlands with permanent water presence on Rhodes (Paragkamian and Katsadorakis 2007). In the summer, water is only preserved near the springs or in small river

and lake basins along the stream beds and near the estuaries. The available evidence suggests that the occurrences of *M. tuberculata* most likely represent unsuccessful or transient introductions rather than an established population. The finding of empty shells in 2017 and 2021, followed by the observation of live individuals in Rodini Park in September 2022, indicates that the species probably survived for at least one annual cycle and successfully overwintered at least once. However, we cannot exclude that the species was repeatedly introduced during that period and did not survive winter conditions in the wild. A short-term persistence is consistent with the ecological plasticity of *M. tuberculata*, which is known to tolerate a wide range of environmental conditions and to persist temporarily at low densities in suboptimal or marginal habitats following introduction events (Pointier *et al.* 1993; Facon *et al.* 2003). Nevertheless, the repeated failure to detect alive individuals in subsequent surveys, despite targeted searches, argues against the presence of a self-sustaining population. The accumulation of numerous fresh shells at the Zephyros beach, downstream of Rodini Park in 2024 reflects hydrological transport, i.e. seasonal flooding events, increased discharge during heavy rainfall, or episodic flushing of the stream, may have transported shells to the beach. The highly seasonal hydrology of Rhodes, characterized by summer droughts and abrupt flow changes, may prevent *M. tuberculata* from maintaining stable populations despite temporary survival. Taken together, the sporadic occurrence of shells, the very low number of observed alive individuals, the absence of juveniles, and the lack of continuous records suggest that *M. tuberculata* probably failed to establish a viable population in Rodini Park until now. Nonetheless, the probable survival over at least one winter highlights that local conditions can intermittently support the species, emphasizing the importance of continued monitoring. Given the park's role as a hotspot for aquarium-mediated introductions, repeated release events are likely, and future introductions may still result in establishment under more favourable climatic or hydrological conditions.

In Rodini Park, *M. tuberculata* co-occurs with the native freshwater snail *Melanopsis wagneri* and the also introduced bladder snail *Physella acuta* (Draparnaud, 1805) (Heterobranchia: Physidae). The presence of *M. tuberculata* in Rodini Park is not unexpected, as it is the only urban park in Rhodes that supports a permanent, year-round freshwater stream, providing relatively stable conditions for aquatic organisms. Moreover, the occurrences of *M. tuberculata* and *P. acuta* are not the first cases of non-indigenous freshwater species recorded from the park. Several other non-indigenous freshwater species have already been documented in Rodini Park, including the American Pond Slider *Trachemys scripta* (Thunberg, 1792) (Kalaentzis *et al.* 2023) and the Chinese Stripe-necked Turtle *Mauremys sinensis* (Gray, 1834) (Kalaentzis and Louizidou in press). Introduced fish species are also present, notably the Western Mosquitofish *Gambusia affinis* (Baird & Girard, 1853), as well as ornamental cyprinids such as Koi *Cyprinus rubrofuscus* Lacepède, 1803 and Goldfish *Carassius auratus* (Linnaeus, 1758) (Kalaentzis pers. obs.). The repeated detection of non-native aquatic taxa highlights the park's role as a focal point for aquarium- and pet-trade-mediated introductions and underscores the vulnerability of small, urban freshwater systems to biological invasions.

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