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First records of *Mauremys sinensis* in Portugal: a consequence of inadequate policies applied to the exotic pet market

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Abstract Commercial success of a pet species predicts its invasiveness, making the most traded species more likely to become introduced. Turtles are among the most traded species, making it critical to monitor their introduction, and in Portugal several invasive turtle species have been detected in nature. This study reports the first official record of *Mauremys sinensis* and lists its unofficial records in Portugal. This is a critically endangered species in its native range but invasive out of its native range. Two *M. sinensis* individuals (one adult male and a juvenile) were found in a lake near Évora, alongside native *Mauremys leprosa*. Additionally, iNaturalist database analysis revealed 14 citizen science records of this species in 10 municipalities in Portugal since 2021 These records were located from North to South of continental Portugal but also in the Madeira Island. The presence of invasive turtles can impact native species through competition, predation, disease transmission, and hybridization. Pet trade is the primary source of these species, and legislation has been ineffective in preventing their introduction. This study also highlights the need for comprehensive strategies, including whitelists and blacklist, to address the invasive pet trade, protect native ecosystems, and prevent further introductions of species like *M. sinensis*.

Keywords Introduced · Chinese stripe-necked turtle · Impacts · Legislation · Invasive

Invasive species are considered a major environmental problem by the scientific community (Pyšek et al. 2020). The invasiveness of these species is determined by their characteristics, such as generalist feeding and high reproductive output (Havel et al. 2015), but also by their commercial success and the most traded species are the most likely to become invasive (Gippet and Bertelsmeier 2021). Freshwater turtles are one of the most traded aquarium pets as well as one of the most released (Bush et al. 2014; Banha et al. 2019; Maceda-Veiga et al. 2019). When released, exotic turtles may compete with native ones for food and basking places, displaying aggressive behaviour towards native ones (Pérez-Santigosa et al. 2011; Polo-Cavia et al. 2014). Often, these introduced turtles, co-introduce diseases and parasites (Dembkowska-Kutrzepa et al. 2018). In Portugal, *Graptemys pseudogeographica*, *Trachemys scripta* and *Pseudemys concinna,* are commonly kept as pet (Banha

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et al. 2019). All the above species, plus *Pseudemys nelsoni,* have been identified as exotic in mainland Portugal (Anastácio et al. 2019), and are all included in the national law (Diário da República 2019), which legislates the detention, introduction and control of exotic species, and also includes the Portuguese list of invasive species.

Mauremys sinensis is a freshwater pet turtle species native to eastern Asia, where it is classified as critically endangered (Li et al. 2021). This species inhabits lentic and slow-moving lotic systems (Chen and Lue 2009). Its introduction has severe consequences to the native species (Lee et al. 2019; Sancho et al. 2020) and therefore it is categorised as invasive (Oficialdegui et al. 2023). In Europe, there are several confirmed records of its introduction in Spain (outside the transboundary rivers), Italy and Slovakia (Blasio et al. 2021; Jablonski et al. 2018a, b; Sancho et al. 2020), but none in Portugal. In this article we describe the first official record of *Mauremys sinensis* in Portugal.

During the months of September and October of 2023, after a previous visual detection of an unknown turtle species, we sampled three times a small lake (~3 ha) in Évora, Portugal (38.568831°, −7.923656°), which is a very popular site among locals. In each sampling occasion, we installed 2 to 6 hoop nets and for each turtle captured we measured its straight carapace length (SCL), straight carapace width (SCW), plastron length (PL), plastron width (PW) and weight.

During sampling we collected 15 freshwater turtles of which 13 were native *Mauremys leprosa* and 2 were *Mauremys sinensis* (Fig. 1). One of the *M. sinensis* was captured in a trap that had two *M. leprosa*. *M. sinensis* were identified based on the following characteristics: at least eight yellow stripes at the head and neck, cream to yellow spots on peripheral plate and bridge, and keels present on the carapace (McCord and Iverson 1992; Fig. 1). Visually, *M. sinensis* specimens were in good health condition, although the juvenile had some carapace scars (presumably bite marks) and an old coccygeal fracture. The biometric measures, the sex and the age of the two *M. sinensis* are presented in Table 1.

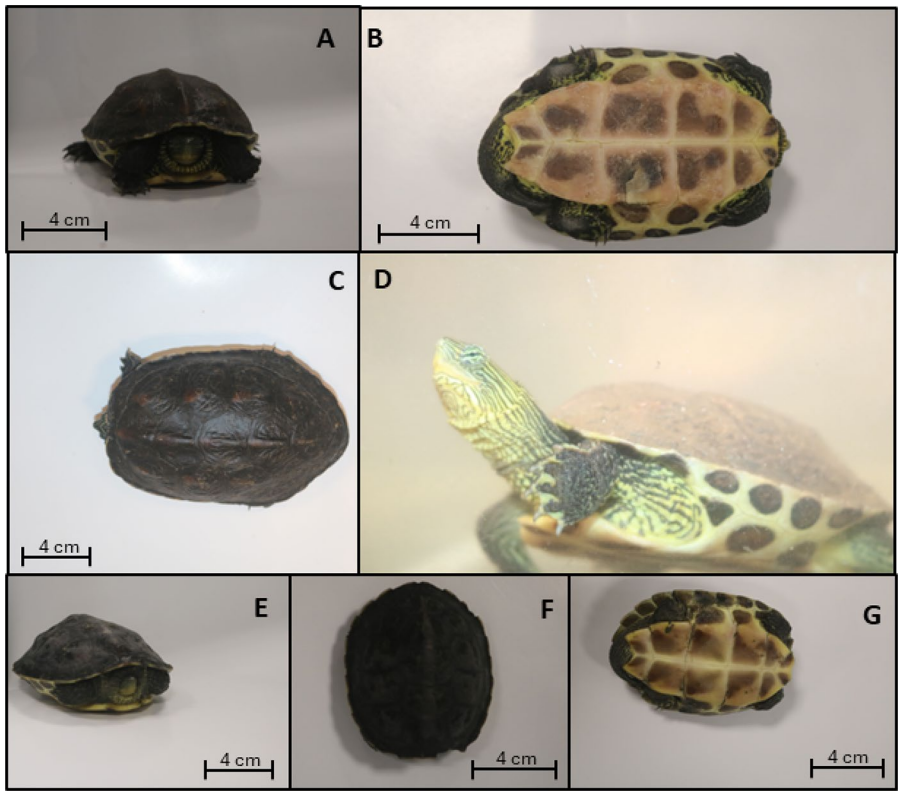

Fig. 1 Photos of *M. sinensis* ID 1 (see Table 1): **A**—Side view; **B**—Ventral view **C**—Dorsal view; **D**—photo taken in an aquarium. Photos of *M. sinensis* ID 2 (see Table 1): **E**—Side view; **F**—Dorsal view; **G**—Ventral view. *M. sinensis* were identified based on the following characteristics: at least eight yellow stripes at the head and neck, cream to yellow spots on peripheral plate and bridge, and keels present on the carapace (McCord & Iverson 1992; Xia et al. 2011)

Table 1 Biometric measures, sex and age of the two *M. sinensis* captured

Specie	ID	Sex	Weight (g)	SCL (cm)	WCL (cm)	PL (cm)	PW (cm)	Age
Mauremys sinensis	1	Male	220.00	11.80	7.75	9.70	5.00	Sub-adult
Mauremys sinensis	2	–	125.00	8.60	6.50	6.85	3.80	Juvenile
Mean			172.50	10.20	7.13	8.28	4.40	
SD			47.50	1.60	0.63	1.43	0.60	

SCL- straight carapace length; SCW- straight carapace width; PL- plastron length; PW- plastron width

This is the first scientific record of the presence of *M. sinensis* in Portugal, and this record demonstrates its sympatric occurrence with *M. leprosa*. Although in this work we describe the first official record, several unofficial records have been made by citizen science platforms and are available in the iNaturalist Database (Fig. 2). Between 2000 and 2022, 88590 live individuals of *Mauremys sinensis* were imported to Portugal (CITES Trade Database 2023), which demonstrates that *M. sinensis* is currently available

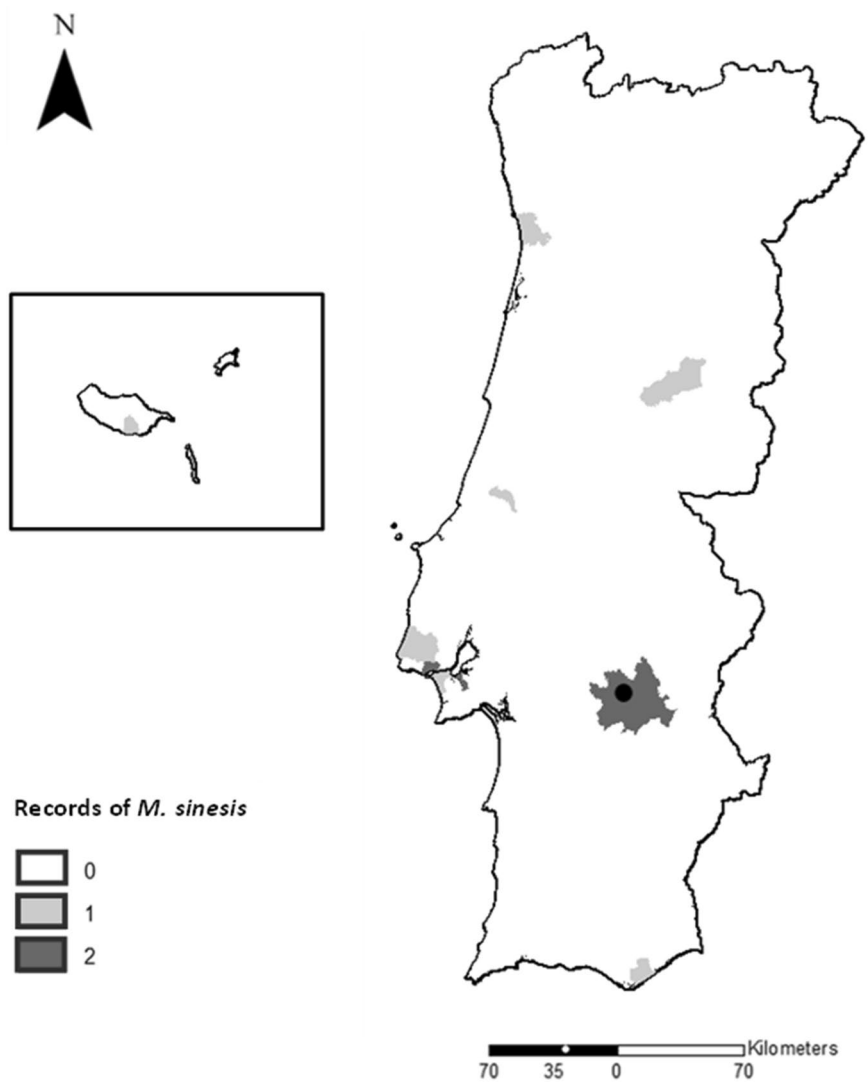

Fig. 2 Map of *M. sinensis* records per municipality, retrieved from iNaturalist (https://www.inaturalist.org/observations?place_id=7122&taxon_id=39950). Black circle—site of the first official record in Portugal. The Azores are not shown because no *M. sinensis* was recorded there. Due to the endangered status of *M. sinensis*, the exact coordinates are not provided by iNaturalist

for sale in Portugal and has been released by pet owners, with potential ecological impacts. In spite of its great utility, the use of citizen science platforms has several issues. First, many users are not experts, and so misidentify the species (Dickinson et al. 2010; Durso et al. 2021). To minimize this, some platforms, unlike INaturalist, have a validation process of the uploaded photo (Dickinson et al. 2010), but even so, low quality photos may compromise identification. Secondly, the same user may upload various photos of the species observed in the same location, that results in duplicates (Durso et al. 2021). The opposite may also happen, with one photo having multiple individuals and even different species. Finally, some users may fake records, uploading photos not corresponding to a given location or that were taken in captivity. Additionally, citizen science is spatially biased to highly populated areas and to "prettier" species (Dickinson et al. 2010; Durso et al. 2021).

The biometric measures taken from the two *M. Sinensis* (Table 1) were consistent with biometric measures from studies in the turtles' natural range (Chen and Lue 1998) as well as with studies outside its natural range (Blasio et al. 2021; Jablonski et al. 2018a, b). Based on SCL extrapolation (Chen and Lue 1998) the juvenile turtle was estimated to be 2 years old, and the adult turtle 4 to 5 years old. The weight of the turtles was within normal weight for their age class (Chen and Lue 1998). We only used SCL because the relation between weight and age was only studied for farm raised turtles (Li et al., 2021).

In comparison with the congeneric portuguese native species, *Mauremys s.* has a larger clutch sizes, of 7–17 eggs (Bertolero and Busack, 2017; Chen and Lue 1998) which may lead to higher reproductive output and also may increase its invasiveness. Both species have a population structure mainly composed by adults, and an opportunistic omnivorous diet (Bertolero and Busack, 2017; Chen and Lue 1998). Hibernation was only recorded in *Mauremys leprosa* (Bertolero and Busack, 2017).

Dietary choices of *M. sinensis* are a cause for concern since it may overlap with the native turtles (Chen and Lue 2009; Pérez-Santigosa et al. 2011). However, this must be interpreted with caution since Chen and Lue (2009) studied *M. sinensis* in its native range. *Salmonella spp.* was identified in captive *M. sinensis* which may pose an additional threat to native species (Back et al. 2016). It is known that *M. sinensis* is capable of hybridising with some species of the same genus (Lee et al. 2019; Xia et al. 2011), but also with species of other genus and families (Huang et al. 2021). In Spain, there are reports of hybrid turtles between *M. sinensis* and *M. leprosa* (Sancho et al. 2020). Despite the impacts of these potential hybrid individuals are unknown, they may affect freshwater turtle populations (Sancho et al. 2020) potentially leading to introgression (Lee et al. 2019).

To reduce the introduction rate of several invasive species in Europe, council regulation (EC) 338/97 (1996) was created, prohibiting the trade of several species, including the freshwater pet turtle *Trachemys scripta.* This was not enough to reduce the spread of *T. scripta* and other invasive species, and so, the regulation (EU) 1143/2014 (2014) was implemented which defines measures to prevent, minimise and mitigate the introduction and spread of non-native species present in the list adopted by the commission implementing regulation (EU) 2016/1141 (2016). In this list, the only species of chelonians was *T. scripta*, and therefore it was the only chelonian species for which trade, ownership and reproduction was banned in the EU. Not being able to sell *T. scripta* anymore, pet-shops began to sell other species of freshwater turtles, such as *Pseudemys concinna* and *Graptemys pseudogeographica*, that became widespread among pet-owners (Banha et al. 2019). These species were rapidly introduced into the wild, and in response the Portuguese government created the law 92/2019 (Diário da República 2019), which includes a list of invasive species. This new list includes *Trachemys spp.*, *Pseudemys spp.* and *Graptemys spp.*, and other turtle species that do not have large commercial interest. With the ban of commercialization of the listed species, new species began to be traded, like *Mauremys sinensis*.

Prohibition lists, commonly known as "blacklists", have some negative aspects, namely: (1) not reducing the spread of unintentionally introduced species; (2) inclusion mainly of species that were subjected to risk analysis, while not including newly traded species; (3) not generating financing support to control and manage the already introduced species; (4) not preventing the substitution of banned species by similar species, e.g. the substitution of *T. scripta* by *M. sinensis*; and lastly, (5) not including all the invasive species already introduced (Simberloff 2006; Zamora-Marín et al. 2023). For example, the EU regulation only

includes 8% of the non-indigenous freshwater species introduced in the Iberian Peninsula, partially because almost 18% of these species have their native range in Europe (Zamora-Marín et al. 2023). Simberloff (2006), states that blacklists must be created together with whitelists, that are lists of species allowed to be traded. To create whitelists there must be a risk analysis to ensure that the species in the list will not have significant impacts if introduced (Simberloff 2006). In the Portuguese blacklist, *M. sinensis* is not present and so it can be legally sold at pet-shops. The unregulated sale of *M. sinensis* increases the potential invasiveness of this species (Gippet and Bertelsmeier 2021), thus this will be reflected in Portugal.

M. sinensis may represent a serious threat to Portuguese ecosystems. It can easily hybridise with members of the same and different families (Sancho et al. 2020). This means that, apart from *M. leprosa*, *Emys orbicularis* may also be affected (Sancho et al. 2020). Since the pet trade is the main introduction pathway for *M. sinensis* as well as for other freshwater turtles, innovative strategies are needed, because it seems that the current legislation, and other commonly used legal mechanisms, are not the solution for the problem of invasive species with commercial interest.

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Data availability The authors confirm that the data supporting the findings of this study are available within the article.

Declarations

Conflict of interest The authors have no conflicts of interest to disclose.

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