

Communication

A New Invasion of the Common Slider on a Mediterranean Island (Lesvos, Greece): A Potential Threat to Native Terrapin Populations?

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Abstract: Island wetlands are considered crucial to biodiversity due to their unique ecological, biogeographical, and socioeconomic dynamics. However, these habitat types are particularly vulnerable to invasion; invasive species can cause severe ecological, evolutionary, and epidemiological impacts on native species. One of the most important invasive species, the common slider *Trachemys scripta*, an opportunistic inhabitant of freshwater habitats, has been released in multiple localities across Greece in recent years, and has expanded its range through random and unintentional releases in the Aegean islands. Since its first documented record on the island of Crete in 1998, the species has been observed on six more islands. Here, we report, for the first time, two subspecies of the common slider (*T. scripta scripta* and *T. scripta elegans*) on the wetlands of the island of Lesvos. We discuss the potential threats to native terrapins and we examine whether the introduction of this invasive species has affected native terrapins by monitoring their populations for 12 consecutive years (2010–2022). We found the common slider in 3 out of 110 wetlands surveyed. At one site, we document the presence of invasive terrapins belonging to two different subspecies. In all surveyed wetlands, we found stable populations of the two native freshwater terrapins, *Mauremys rivulata* and *Emys orbicularis*, with the first species found in much larger populations than the second. Despite these reassuring findings, the presence of this introduced species on the island of Lesvos raises serious concerns regarding its negative effects on the local terrapin populations. We propose that systematic and thorough monitoring of insular wetlands, as in the case of Lesvos, should be adopted on other islands as well, with priority on those where the common slider has been recorded.



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1. Introduction

Invasive alien species (IAS), along with habitat loss and climate change [1], have long been recognized globally as a major driver of biodiversity decline [2–4]. The IAS introduction rate is still accelerating [5] as there has been a 40% rise since 1980, while the IAS number per country has increased by 70% over the last fifty years [6]. IAS can (a) alter the structure and functioning of ecosystems [7], (b) negatively affect ecosystem services [8], and (c) drive native species populations towards endangerment and/or extinction through predation, resources competition, hybridization, and pathogen introduction [9,10]. For these reasons, they are considered the second most important threat [11] regarding any biological scale [12] with particularly high impacts on island ecosystems [13–15].

Islands, despite their small extent in comparison to continental areas, host more than half of the known species extinctions and more than one-third of the critically endangered

species worldwide [16]. Their isolation and size as well as their unique ecological, biogeographical, and socioeconomic dynamics [15,17], which include a stable habitat diversity, species with small population sizes [18], and a stable status regarding competition, predation, and parasitism among species [19], makes them particularly vulnerable to the impacts of IAS [13]; this is the reason that islands are referred to as hotspots of established alien species across multiple taxonomic groups [1,20]. At the same time, the islands' vulnerability to IAS is highly influenced by the human-mediated introduction of alien species, mainly by trade and transportation [21], leading to the extinction of native species [22] and to the degradation of their fragile habitats, with apparent implications for conservation.

In the Mediterranean biome, a well-known biodiversity hotspot [23], one of the most important but also sensitive ecosystems are island wetlands [24]. Due to their transitional nature, they are considered critical for biodiversity conservation as they provide a variety of ecosystem functions and services to support viable populations of terrestrial, aquatic, and semi-aquatic species [25,26]. Nowadays, Mediterranean wetlands are under threat from IAS as they host substantially higher numbers of them than other habitats [27].

In such sensitive ecosystems, alien amphibian and reptile species can cause severe ecological, evolutionary, epidemiological, and socio-economic impacts [28,29]. Among them, the common slider, *Trachemys scripta* (Thunberg in Schoepff, 1792) (Testudines: Emydidae), an opportunistic inhabitant of freshwater habitats, classified as one of the "World's Worst Invasive Alien Species" [30], has been introduced in many parts of the world through multiple pathways, but mainly through pet trade [31]. The common slider has been proven to be one of the most successful invaders around the world [31], as beyond its survival, the species has managed to breed successfully when the conditions are suitable, in many countries [32].

In the Mediterranean basin, there are numerous records of the species, including successful reproduction in the wild. Spain probably has the largest population of the common slider in the Mediterranean, being distributed over the largest part of its mainland as well as its insular part [33–39]. Other countries such as Portugal, France, and Italy also have populations of the species, with confirmed breeding in some locations [40–46]. In the eastern part of the Mediterranean, the species is also present in many countries, such as Turkey [47], Jordan [48], Israel [49,50], and Cyprus [51]. In the Balkan peninsula (Croatia, Montenegro, Serbia, Romania, and Bulgaria) wild populations of the common slider have also been found [52–57].

In Greece, the presence of the species is quite noticeable in many areas. The first sightings of the common sliders took place during the early 1990s and have continued steadily from 2000 until today [58,59]. The metropolitan area of Athens was the first area where the common sliders began to appear. From the mid-2000s and onwards, an increased number of sightings has been recorded in several places in Greece [58]. In insular Greece, as in many other islands around the world [60], the number of IAS introduction events has increased during the last decade. The common slider was recorded for the first time in Crete, in 1998, and from then on it has been observed on other islands both in the Ionian sea and in the Aegean Archipelago [58,61,62]. To date, common sliders have been found in the islands of Kos [63], Samos [64], Rhodes [65], Chios [65], Icaria [66], and Thasos [67].

A systematic effort is essential for the development and implementation of conservation plans [68]. However, despite the abundance of herpetological surveys on Greek islands [64,69], there has been no systematic effort to document the possible presence of IAS and/or their coexistence with indigenous freshwater terrapins in any of the wetlands of the Aegean Archipelago until now.

In this work, we report the presence, for the first time, of two subspecies of the common slider (*T. scripta scripta* Schoepff, 1792 and *T. scripta elegans* Wied, 1838) on the wetlands of Lesbos Island, Greece. Furthermore, we examine whether the presence of this alien species is a potential threat to the native terrapins by monitoring their populations for twelve consecutive years.

2. Materials and Methods

2.1. Study Area

Lesvos, the third-largest island of Greece, located in the north-eastern Aegean Sea, is a natural bio-laboratory [70], with an area of 1632.8 km², and a large number of wetlands of all types [71]. The island encompasses 85 officially mapped and protected [Presidential Decree (Government Gazette 229/AAT/2012)] wetlands, both natural and artificial, with a total area of 13.77 km², which ranks it second among the Aegean islands, after Crete. The island is hilly with a maximum altitude of 968 m (Mt. Lepetymnos). The eastern and southern parts of the island are covered mainly by traditional olive groves (*Olea europaea*), while in its central part extensive areas of continuous and homogeneous pine forests (*Pinus brutia*) are found. In the western and northern parts of the island shrubby vegetation and phrygana grows along with oak tree patches (Figure 1). Due to its large size, Lesvos hosts a high number of biota, while its diversity is much influenced by the east due to its vicinity to Asia Minor, thus constituting an island where Anatolian species meet with the Mediterranean ones. This promotes the existence of a variety of terrestrial, aquatic, and semi-aquatic herpetofauna species. The island's climate is Mediterranean, characterized by cool-moist winters with a mean temperature of 9.6 °C in January, and warm-dry summers with a mean temperature of 27.0 °C in July (Mytilene airport) [72]. The mean annual rainfall varies from 725 mm in the east to 415 mm in the west of the island, with little or no rain between May and September [73].

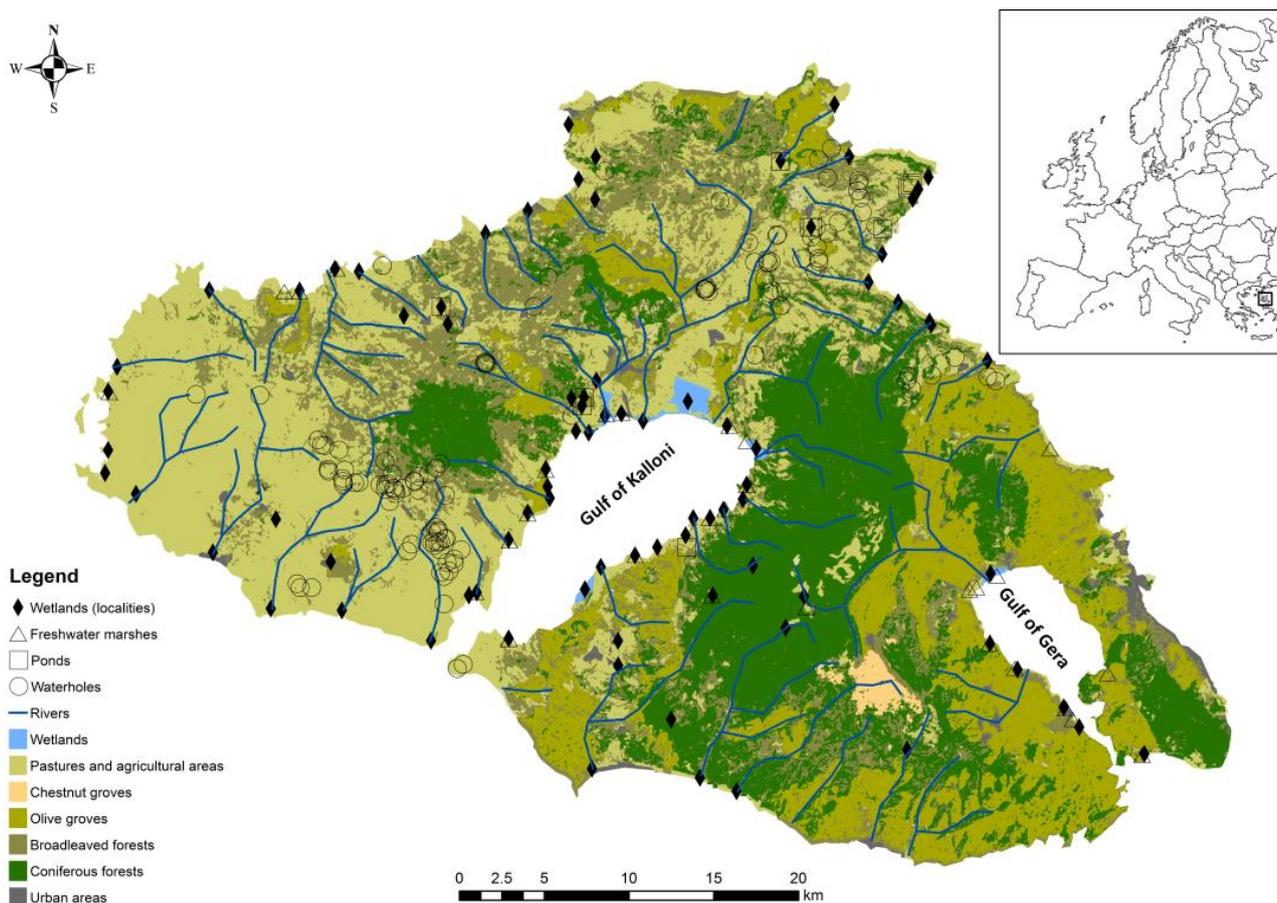


Figure 1. Distribution map of the island of Lesvos showing the main wetlands, freshwater marshes, ponds, and waterholes (giolia), along with its main habitat types.

2.2. Mapping of Wetlands and Data Collection

In order to collect all possible sightings of the alien herpetofauna on the island of Lesbos, we first had to map the wetlands and rivers of the island. For this, we used available spatial data derived both from the open platform of geospatial data and services for Greece ([Geodata.gov.gr](https://geodata.gov.gr) (accessed on 10 October 2022)) and the Biodiversity Conservation Laboratory at the University of the Aegean. Moreover, in order to obtain information regarding the presence of small ponds, waterholes, channels, streams, and other freshwater sources in which there was a possibility of IAS presence, we used the knowledge of the island's inhabitants, birdwatchers, and other naturalists. We evaluated this information by systematically searching the whole island in all the areas that had been indicated to us. We focused our searches in areas where livestock farming exists, as the "wetland" potential of these areas is enriched by the impressive network of reservoirs and/or man-made waterholes, named "giolia", used for field irrigation and livestock watering. In cases where access to these reservoirs was not possible, due to fencing, we excluded them from our analysis. In total, we recorded 123 new wetland-type sites, in addition to the 85 officially recorded, of which 115 were the artificial "giolia", four were ponds, and four were freshwater marshes (Figure 1).

From this set of 208 wetland-type sites, we selected 110 and conducted a standardized annual herpetofauna survey in April and May for 12 consecutive years (2010–2022). Keeping in mind the ecological characteristics of sunbathing terrapins, we conducted each survey during daylight hours from 09:00 to 18:00, on sunny days with temperatures ranging from 15 to 35 °C. The survey team consisted of two researchers (A.C. and Y.G.Z.), with observations made using binoculars and two cameras. Each survey was proportional to the size of the wetland, ranging from a few minutes to several hours. In order to locate and record the terrapins, we used visual encounter in combination with transect and basking surveys. The first method was applied along river banks and all water body types (e.g., dams, lakes, waterholes, estuaries), and the second method in places where there were large native terrapin gatherings. The transect method is widely used for herpetological surveys in both reptilian and amphibian species, while the basking surveys are limited to species that bask at certain times of day and season. We used a combination of methodology techniques, which is recommended when time, staff, and other resources allow, in order to make terrapin detection more efficient [74]. We conducted species identification by examining their morphological characteristics [75]. All data were recorded on an inventory form, which was designed and pilot-tested before its final use (Figure A1).

2.3. Data Analysis

We examined whether the two native terrapin species' populations had shown throughout the years an increasing, decreasing, or stable trend, considering both their population as a whole and individually in the localities where the IAS was observed, by modelling the data with generalized linear models. We chose the Poisson distribution for our models as this is the ideal method of generalized linear modelling in cases where the response variable is a non-negative integer count (in our case, the observed native terrapin counts) [76]. The first year of monitoring was chosen as the baseline for our analyses. All statistical analyses were carried out using SPSS software (v. 25.0. Armonk, NY: IBM Corp.). All the assumptions required were met and statistical significance was assumed at the 5% level. Summary statistics are expressed as means \pm standard deviations (SD).

3. Results

3.1. Localities of Common Slider Presence on the Island of Lesbos

From the 110 wetland-type habitats in which we conducted the herpetofauna survey, we found invasive alien terrapins in three localities. In particular, on 15 April 2016, at 12:30 h, we observed, for the first time on the island of Lesbos, an adult individual of *T. scripta elegans*, at the Vouvaris river estuarine (39°09'36.0" N, 26°17'34.6" E) (Figure 2), which is located at the central part of the island, close to its largest wetland "Alykes Kallonis".

The terrapin was seen swimming among approximately 130 individuals of the native species *Mauremys rivulata* Valenciennes, 1833 (Testudines: Geoemydidae), and had all the diagnostic characteristics of the subspecies [77].

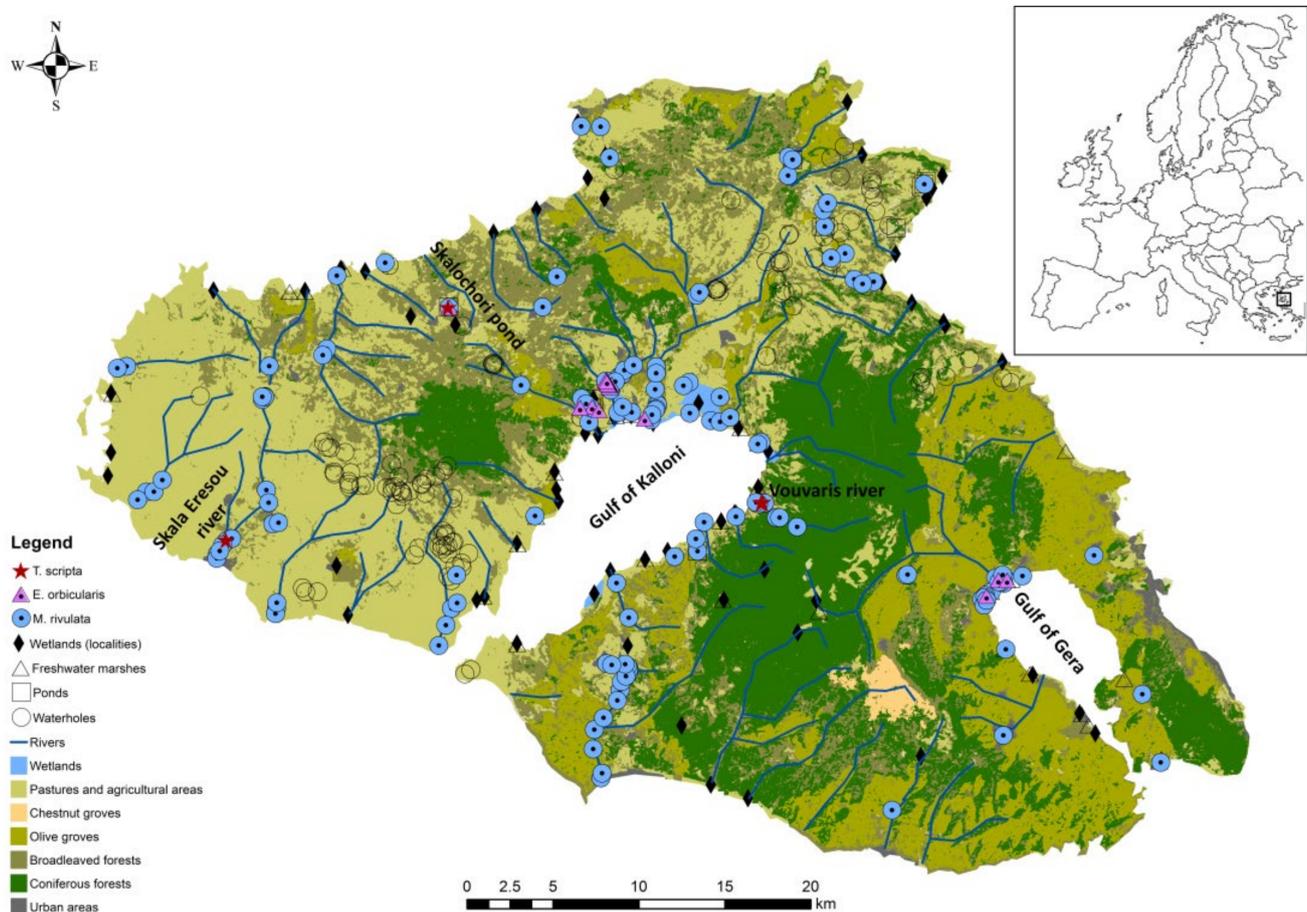


Figure 2. Main localities of occurrence of the introduced *T. scripta* and the native species, *M. rivulata* and *E. orbicularis* on the island of Lesvos.

Two years later, on 8 May 2018, at 13:37 h, on the exact same locality, we observed two adult individuals of subspecies of the common slider, the *Trachemys scripta scripta* and the *Trachemys scripta elegans*, sharing the same estuarine (Figure 3). Furthermore, on 24 May 2018, at 17:03 h, we observed an adult individual of *T. s. scripta* at the Skala Eresou river mouth (Psaropotamos river) ($39^{\circ}8'21.09''$ N, $25^{\circ}55'31.49''$ E), located in the southwest part of the island (Figure 2). The animal was seen also swimming among 220 native terrapins in this area (*M. rivulata*). We also found an adult *T. s. scripta* in a third locality, “Skalochoi pond” ($39^{\circ}16'0.78''$ N, $26^{\circ}5'6.64''$ E) (Figure 2), on 24 April 2019. The individual was also swimming next to many *M. rivulata* individuals, while one *Emys orbicularis* Linnaeus, 1758 (Testudines: Emydidae) was in the same pond but at a further distance. From 2019 and onwards, we have observed the common slider in these three localities in all our repetitive herpetofauna surveys. In total, the species was seen sixteen times during the years from 2016 to 2022, however, the individuals are probably the same as in our first observations, as they have the same head and shell marking patterns.

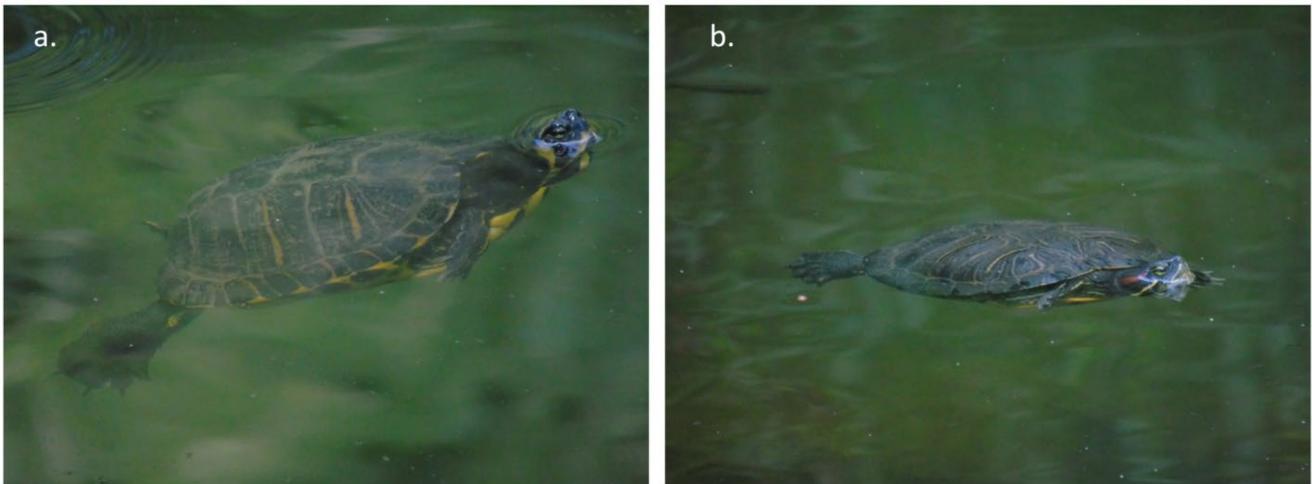


Figure 3. Photographic evidence of the presence of the introduced common slider and its two subspecies on the island of Lesbos, Greece: the coexistence of *T. s. scripta* (a) with *T. s. elegans* (b) in the Vouvaris river mouth.

3.2. Population Trends of the Native Terrapins

Regarding the presence of the native freshwater terrapins, *M. rivulata* and *E. orbicularis*, we found stable populations in all habitats related to the species' ecology, with the first having much larger populations than the second (Figure 4). In particular, we observed *M. rivulata* individuals in 83 localities, while *E. orbicularis* was found in just 6 wetland-type habitats. Their populations ranged from a few individuals in ponds and waterholes to a few hundred in larger water bodies. *M. rivulata* individuals varied between 5342 and 5522 (5425.15 ± 58.02), while *E. orbicularis* between 68 and 83 (74.15 ± 4.27). Their population trends, for both the native terrapins, throughout the years, did not vary significantly ($p > 0.05$) and thus, we can conclude that it remained stable (*M. rivulata*: $b = 5.395 \times 10^{-7}$, S.E. = 2.755×10^{-6} , $p = 0.845$; *E. orbicularis*: $b = -8.722 \times 10^{-6}$, S.E. = 2.357×10^{-5} , $p = 0.711$) as it can be seen in Figure 4. In the three localities, where we recorded the coexistence of *M. rivulata* and *T. scripta*, the population of *M. rivulata* was also stable (Vouvaris river: mean = 126.30 ± 6.54 , $b = -1.632 \times 10^{-5}$, S.E. = 1.806×10^{-5} , $p = 0.366$; Skala Eresou river: mean = 332.00 ± 10.27 , $b = 1.723 \times 10^{-6}$, S.E. = 1.114×10^{-5} , $p = 0.877$; Skalochoori pond: mean = 82.53 ± 5.20 ; $b = -7.836 \times 10^{-6}$, S.E. = 2.234×10^{-5} , $p = 0.726$), following the same pattern as the total population, with no signs of a significant downward trend (Figure 4).

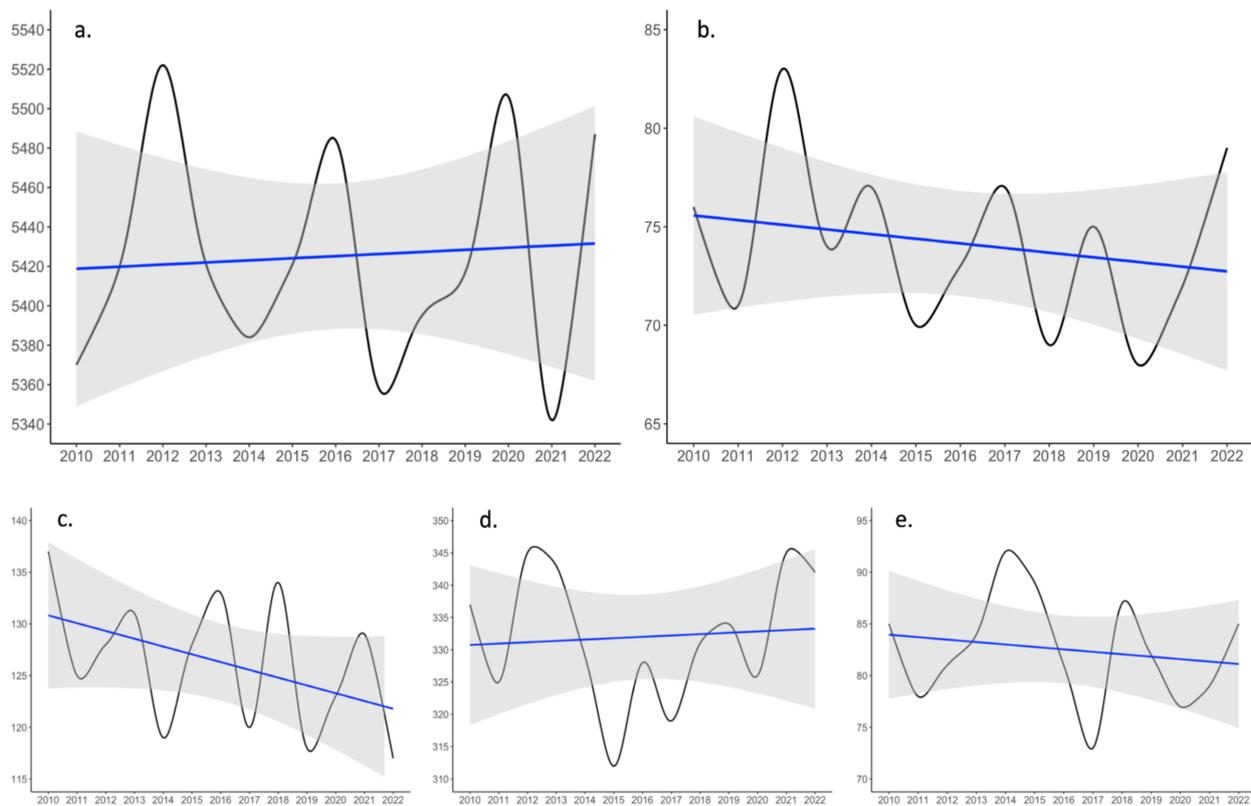


Figure 4. Population fluctuations and trends of the two native terrapins on the island of Lesbos: (a) *M. rivulata*, (b) *E. orbicularis*, (c) *M. rivulata* in the Vouvaris river, (d) *M. rivulata* in the Skala Eresou river, and (e) *M. rivulata* in the Skalochori pond; The blue line indicates the population trend based on the Poisson distribution and the shaded area represents the confidence intervals. In all cases, the native terrapin populations have remained stable throughout the years. It is worth mentioning that there was no *E. orbicularis* in the Vouvaris river, nor in the Skala Eresou river. In the Skalochori pond, there was one individual which we observed during the 2019 and later surveys.

4. Discussion

In this study, we report, for the first time, the appearance of two subspecies of the common slider on the Greek island of Lesbos. The presence of this species at three different wetland sites, of different sizes and with different native terrapin abundances, is a particularly important finding. The connection concerning the presence of this IAS with the native terrapins' population trends which have been monitored for twelve years constitutes another important element of our work. In addition, due to the fact that *M. rivulata* is considered a widespread and not threatened species, there have not been any wide-range studies for its population trends. At the same time, despite the global population decline of *E. orbicularis* and the widespread habitat loss through much of its range [78], there is also no other study related to its population size.

In the first locality, the Vouvaris river mouth, where we documented the appearance of the Common slider back in 2016, we established the coexistence of the two subspecies (*T. s. scripta*, *T. s. elegans*), which can hybridize with each other [79,80], with the Western Caspian terrapin (*M. rivulata*); this provides another important piece of information which potentially concerns the effect of the common slider on native terrapins. To the extent of our knowledge, this is the first time in which there is an officially documented record of this coexistence in the Aegean archipelago; there is also another case on the island of Zakynthos, in the Ionian Sea [61]. At the same time, it is worth mentioning the presence of this IAS in the Skalochori pond, as two species of native terrapins inhabit this pond, even if the occurrence of *E. orbicularis* there is due to accidental transportation. As in the Vouvaris and the Skalochori sites, so in the Skala Eresou river mouth, the common slider co-occurs

with the native terrapins. However, we did not observe an established population nor a reproduction of this introduced species in any wetland-type habitat. The three localities in which we found the alien species are well-known and easily accessed terrapin spots next to the main roads of the island, making them “ideal” places for someone to release an unwanted pet.

This coexistence of native and alien terrapin species has been observed not only on the island of Lesvos but on several other islands of the Aegean archipelago. The common slider coexists with both native terrapin species on four islands and only with the Western Caspian terrapin on a further four islands (Table 1). The two species of native terrapins (*M. rivulata*, *E. orbicularis*), both of which are under strict protection status, can be found in several more Aegean islands [65]. The Western Caspian terrapin is more widespread; it is present in thirty of the islands and its populations range from a few to thousands of individuals per island. The European pond terrapin has a significantly lower population occurring only on seven islands [65,69,81] (Table 1).

Table 1. Presence + and possible presence (+) of the freshwater turtles in the Greek Aegean islands.

Greek Aegean Islands	Area (km ²)	Native Terrapins		Introduced Terrapin
		<i>M. rivulata</i>	<i>E. orbicularis</i>	<i>T. scripta</i>
Chalki	28	+		
Gavdos	32	+		
Kimolos	36	(+)		
Psara	43	+		
Skiathos	50	+		
Symi	58	+		
Tilos	63	+		
Serifos	73	+		
Sifnos	73	+		
Mykonos	85	+		
Skopelos	95	+		
Kythnos	100	+		
Amorgos	121	(+)		
Milos	150	+		
Samothraki	178	+	+	
Tinos	194	+		
Paros	195	+		
Skyros	209	+		
Ikaria	255	+		+
Kos	290	+	+	+
Thasos	379	+	+	+
Andros	380	+		
Naxos	428	+		
Limnos	476	+	+	
Samos	477	+	+	+
Chios	842	+		+
Rhodes	1398	+		+
Lesvos	1633	+	+	+
Euboea	3655	+	+	
Crete	8336	+		+

In general, the co-occurrence of the introduced terrapins along with the native terrapins raises serious concerns about the status of the latter. Due to the fact that the common slider has earlier maturity and greater fecundity than native terrapins [33], both the presence and the reproductive potential of this IAS, especially in sensitive ecosystems such as the insular Aegean wetlands, would probably cause negative effects on the local terrapin populations that share equivalent ecological niches. In such cases, the common slider has some advantages that enhance its ability to adapt immediately to new environments: (a) tolerance to

a wide range of temperatures and ability to move longer distances than the native terrapins [82], (b) fewer competitors due to the absence of sympatric terrapin species in the new environments in which they have been introduced [83,84], (c) reduced ability of their prey to recognize them as a new predatory species [85], (d) aggressive and dominant behavior, enhanced by its larger body, during its interactions with native terrapins while accessing food resources [86], (e) anatomical traits which support the faster exploitation of preferable food [87], (f) greater tolerance to pollution and human activity [88], and (g) juvenile sliders outcompeting the native juvenile terrapins [89].

In suitable habitats, these anatomical, physiological, and behavioral advantages of the common slider, favor it in the interspecific agonistic interactions for resources and can lead the species to reach high population sizes [46]. Hence, this successful global-scale invader can cause a variety of adverse effects on local populations of native species. To date, in the Mediterranean basin, many of the negative effects have been documented, with the most serious being (a) basking site competition [90] which causes weight loss and eventually mortality of the native species [40], (b) sunbathing activity reduction of the native terrapins (*E. orbicularis*), which results in the dysfunction of their crucial anatomical (e.g., locomotion) and physiological (e.g., digestion) functions [85,90], and (c) introduction of new microorganisms and diseases as well as the transmission of non-native and native parasites [91–94].

The common slider has long been characterized as one of the primary causes of native terrapin species decline [95]. However, on the island of Lesbos, until now, there has been no obvious effect of this species on native terrapin populations (Figure 4). The examination of the population trend of *M. rivulata* and *E. orbicularis*, throughout our 12-year monitoring on the whole island, showed that their populations have remained stable (Figure 4), with small annual fluctuations. These fluctuations are probably due to (a) reproductive variation, which is influenced by the locality in which they are present and habitat features [96], (b) predation, as in Lesbos there are numerous predators (e.g., *Vulpes vulpes*, *Martes foina*, *Mustela nivalis*) which occasionally hunt these species, especially their eggs and juveniles (pers. obs.), and (c) the observer effect, as the number of terrapins can sometimes be difficult to spot, especially in cases where they are not openly basking or in cases in which they are disturbed [97]. The only case where there is a slight downward trend in the abundance of *M. rivulata* concerns the Vouvaris river mouth. The presence of one or two individuals of the common slider is unlikely to affect an entire local population of native freshwater terrapins, especially since the wetland-type habitats are relatively large enough to support their numbers. Furthermore, we cannot assert that the slight but insignificant decreasing trend which we observed in the Vouvaris river mouth is due to the introduced terrapins, as in addition to the fact that their numbers are extremely low, only six years have passed since we first recorded the IAS.

However, despite these somewhat reassuring findings, the presence of this introduced species on the island of Lesbos should be a reason for concern. An effective legal and regulatory framework for reporting, preventing, controlling, and finally eradicating this IAS should be adopted by the authorities in an effort to minimize its impacts. The native terrapin species' populations on islands where the common slider has been recorded are at risk at all times. The systematic and thorough monitoring of insular wetlands, as in the case of Lesbos, should be adopted on other islands as well, with priority to those where the common slider's presence has been confirmed. For the Aegean islands, the threat of this alien terrapin is lurking, and thus, immediate management measures should be taken to eliminate it while it is early. If the species begins to breed and increase its population, it will become out of control, and then the situation for the native species will be irreversible.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

LESVOS ISLAND – ALIEN TERRAPIN PROJECT			
Survey date: 26/04/2019		Time: 13:45	
Observers name: Apostolos Christopoulos, Yiannis G. Zevgolis		Weather conditions	
Survey area: Mandamados		Cloud cover: 10%	
Coordinates		Air temperature: 23°C	
Latitude: 39°18'15.89"N	Longitude: 26°23'0.09"E		Humidity: 63%
Wetland type: Waterhole		Wind speed: 5m/s N	
General habitat description: A mosaic of macchia vegetation including a few kermes oak and two olive trees			
Human activity: Livestock farming		Count method: Visual encounter	
Terrapin species	Age/Population count	Behaviour/Comments	Other aquatic fauna species:
M. rivulata	Adults (35), juveniles (6)	Basking	Pelophylax bedriagae
			Aquatic insects
General comments: -			

Figure A1. An example of an inventory form that was used in the field surveys.

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