

Current Status of and Threats to Sicilian Turtles

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Abstract: Based on the critical review of the literature published in the last 22 years, an attempt was made to evaluate the current knowledge gap on the distribution and status of the native Testudines taxa occurring in Sicily (namely *Caretta caretta*, *Emys trinacris*, and *Testudo hermanni hermanni*), as well as the available knowledge of the only non-native species with putative viable populations occurring on the island, i.e., *Trachemys scripta*. Summarizing the current information, all of the Testudines species occurring in Sicily showed a fragmented and incompletely-known distribution, and only scarce data are available about their phenology. Moreover, despite their inclusion of international and national laws (Bern Convention, CITES, Habitat directive), all three native species are facing several threats (e.g., habitat alteration, the occurrence of invasive species, parasite spillover) leading to a reduction of their populations on the island. Future monitoring programs on the island should be enhanced, with an emphasis on those taxa in decline. Moreover, involve Citizen Science programs should also be implemented in order to increase the awareness of non-experts and facilitate the monitoring task.

Keywords: *Caretta caretta*; *Emys trinacris*; *Testudo hermanni*; *Trachemys scripta*; Sicily; biological invasions



Citation: Vecchioni, L.; Arculeo, M.; Vamberger, M.; Marrone, F. Current Status of and Threats to Sicilian Turtles. *Diversity* **2022**, *14*, 798. <https://doi.org/10.3390/d14100798>

Academic Editor: Ronald J. Brooks

Received: 26 August 2022

Accepted: 23 September 2022

Published: 25 September 2022

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1. Introduction

The Mediterranean region, due to its heterogeneous physiography and complex palaeogeographical and paleoclimatic history, is a well-known biodiversity hotspot (see [1,2] and references therein). Most Mediterranean islands and islets host a high number of endemic taxa [3,4].

Sicily, with an extension of about 25,700 km², is the largest island in the Mediterranean Sea. It is also an important biogeographical crossroad, thanks to its central position between Africa and Europe and between the western and eastern sub-basins of the Mediterranean Sea [2,5–7]. Nowadays, the island hosts a diverse fauna, with 5.5% of endemic taxa [8] (e.g., within the Sicilian herpetofauna, *Bufotes boulengeri siculus*, *Emys trinacris*, *Podarcis waglerianus*, *Podarcis raffonei*, see [9–13]). Unfortunately, Sicilian fauna is nowadays heavily affected by various threatening factors, such as spreading urbanisation, intensification of agricultural activities, climate change, and biological invasions [14–16]. Among these threats, the latter is possibly the most concerning, since it can heavily affect the native biota, by altering its structure and assemblage composition, and leading to a significant loss and degradation of native biodiversity ([17] and references therein).

Sicily hosts reproductive populations of three species of Testudines, i.e., the endemic Sicilian pond turtle *Emys trinacris* Fritz, Fattizzo, Guicking, Tripepi, Pennisi, Lenk, Joger and Wink, 2005; the Hermann's tortoise *Testudo hermanni hermanni* Gmelin, 1789; and the loggerhead sea turtle *Caretta caretta* (Linnaeus, 1758). Although these taxa have a considerable conservation interest, being protected by international laws (e.g., they all are listed in the "Habitats" Directive 92/43/EC) and included on the IUCN red list [18–20], exhaustive synoptical information is still missing for the Sicilian populations of even the best-studied taxa. In addition, breeding attempts and putative breeding populations of the

non-native species *Trachemys scripta* (Thunberg in Schoepff, 1792) are also known to occur on the island [21].

The aim of the present work is to review the available information on the distribution and status of Sicilian Testudines populations, with a special focus on the last two decades, in order to summarise the current information and to highlight the knowledge gaps to be more urgently filled.

2. Materials and Methods

The surveyed area considered in this work includes Sicily and the small circum-Sicilian islets. Only those Testudines species present with actual or putative reproductive populations in the study area were investigated.

Since our purpose was to obtain information regarding the current status and distribution of the species in the study area, and in light of the alterations of habitats and land use that occurred in Sicily in the last centuries, the review of bibliographical data was limited to papers published from 2000 onwards. All available data were critically evaluated and, when considered reliable, included in the analyses.

Cumulative curves describing the trend of published scientific papers, between 2000 and the present day, were generated for the three native species analysed in the present study (i.e., *Emys trinacris*, *Testudo hermanni hermanni*, and *Caretta caretta*) and the single non-native species (*Trachemys scripta*) based on bibliographic queries using the Scopus website (<https://www.scopus.com/>, accessed on 26 August 2022). The parameters used for gathering such information were based using the following query structure (searching within article title, abstract, and keywords): “scientific name of the species (AND) Sicil*” (e.g., *Caretta caretta* (AND) Sicil*). Since *Emys trinacris* was described in 2005, and Sicilian pond turtle populations were referred to *Emys orbicularis* (Linnaeus, 1758) in the previous literature, a further query using “*Emys orbicularis* (AND) Sicil*” was carried out for the time span 2000–2005. In the frame of this work, we followed the nomenclature and taxa authorships reported by Corti et al. [22]. However, the reader should be aware that Joyce et al. [23,24] provide alternative clade names of the taxa.

Since all three native taxa discussed in the present paper are threatened by hobby breeders or by amateur photographers, we opted not to provide their distribution maps.

3. Results

Overall, 67 papers indexed in Scopus were published from 2000 to 2022 for Sicilian Testudines (Figure 1). Based on the produced cumulative curves, the scientific papers produced in these last two decades are mostly dealing with *Caretta caretta* and *Emys trinacris* (Figure 2). Conversely, papers on *Testudo hermanni hermanni* faced a severe slowdown from 2016 onwards, and only a few references are available for *Trachemys scripta* (Figure 2). A commented checklist of Sicilian Testudines fauna is reported below.

Order Testudines Batsch, 1788.

Family Cheloniidae Oppel, 1811.

Genus *Caretta* Rafinesque-Schmaltz, 1814.

Caretta caretta (Linnaeus, 1758)—Figure 1A.

Remarks

The loggerhead sea turtle *Caretta caretta* occurs in almost all subtropical and temperate waters around the world; few records are available for tropical waters [22,25,26]. This Cheloniidae used to have several nesting areas throughout the Mediterranean coasts [27,28]; unfortunately, these areas are significantly threatened, due to human activities (mostly coastal development and tourism, see [29] and references therein). *Caretta caretta* is also directly threatened in the Mediterranean Sea due to anthropic activities, e.g., bycatch in fishing activities [28,30–32] and destruction and disturbance of nesting sites [27,33,34]. Furthermore, other biotic factors negatively affect the nesting sites, for example, the occurrence of the ghost crab *Ocypode cursor* (Linnaeus, 1758), which is able to predate nests [35,36] and whose spreading in Sicily is ongoing [37].

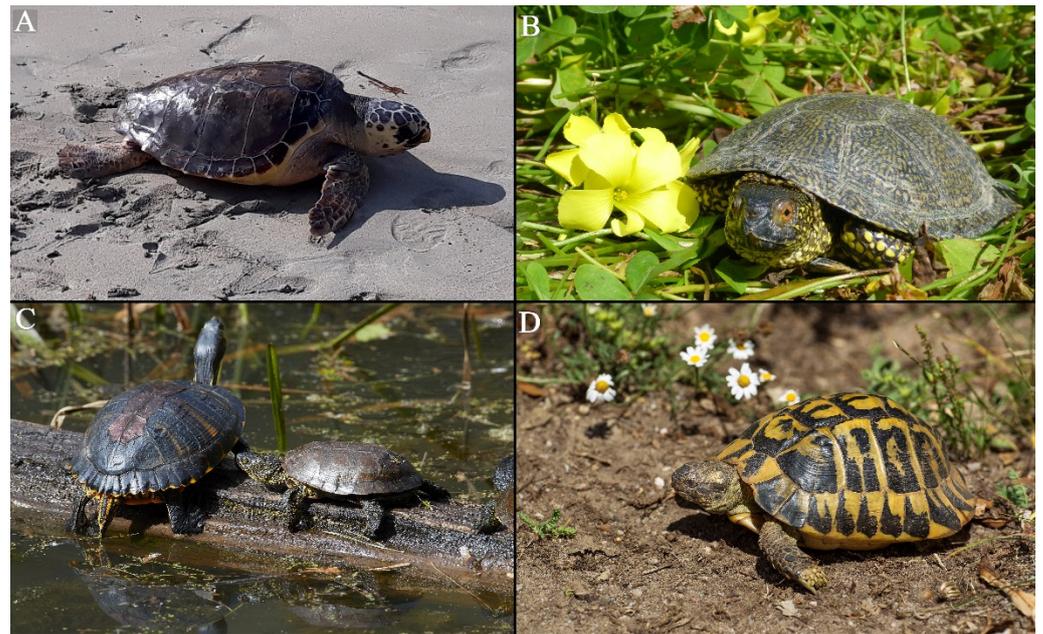


Figure 1. Native and non-native Testudines species in Sicily. (A) *Caretta caretta* from Trapani. (B) *Emys trinacris* from “Gorgo Lungo” at the Oriented Nature Reserve “Bosco della Ficuzza, Rocca della Busambra, Bosco del Cappelliere e Gorgo del Drago” (Godrano, province of Palermo). (C) *Trachemys scripta* and *Emys trinacris* from “Gorgo Lungo” at the Oriented Nature Reserve “Bosco della Ficuzza, Rocca della Busambra, Bosco del Cappelliere e Gorgo del Drago” (Godrano, province of Palermo). (D) *Testudo hermanni hermanni* from “Gorgo Lungo” at the Oriented Nature Reserve “Bosco della Ficuzza, Rocca della Busambra, Bosco del Cappelliere e Gorgo del Drago” (Godrano, province of Palermo). Photo by Enrico Di Girolamo (A), Melita Vamberger (B), and Domenico Margarese (C,D).

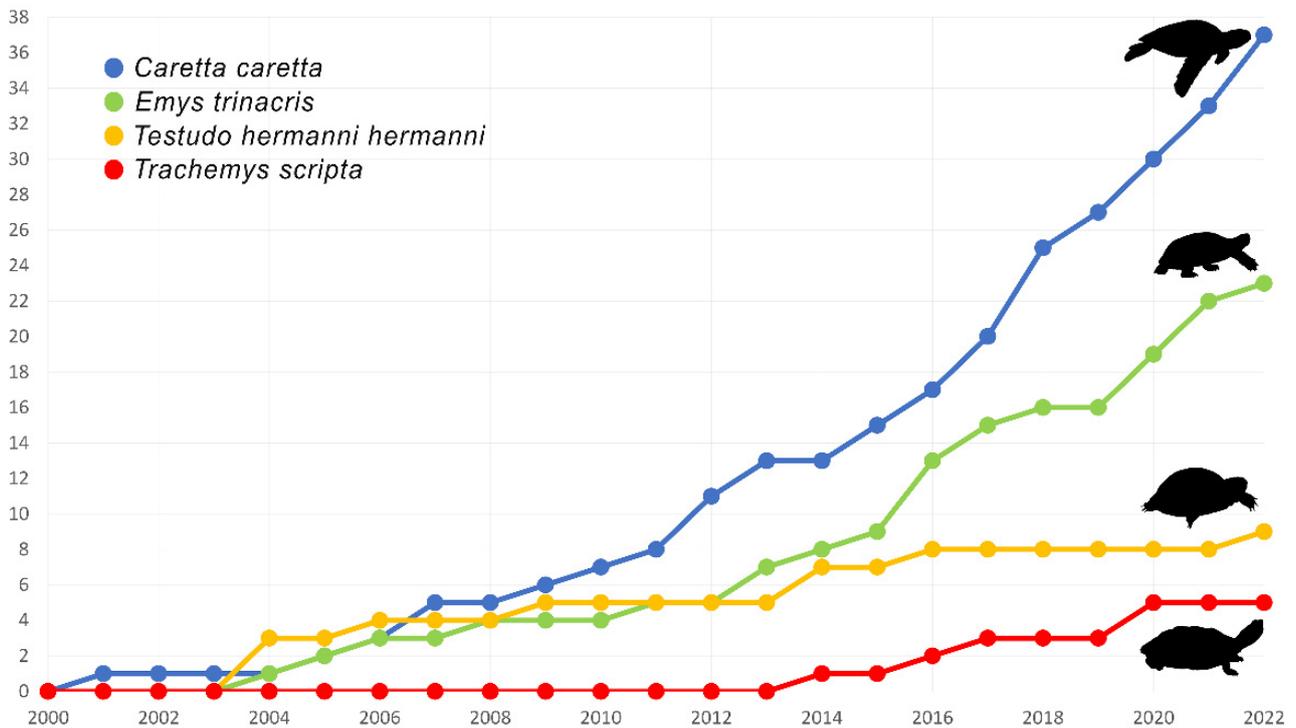


Figure 2. Cumulative curves of a scientific paper on Sicilian Testudines from 2000 onwards.

The known Italian nesting areas of the loggerhead sea turtle are currently mostly located along the southern Italian coasts, i.e., in Calabria, south-eastern Sicily, and the Pelagic archipelago [22,26,34]. Recently, Surdo and Massa [33] and Prato et al. [34] gathered published and unpublished records of egg-laying events of *C. caretta* in Sicily, and reported an increment in the nesting sites on the island when compared to the previous records [38]; however, the authors ascribed this increment to the increased awareness of amateurs and tourists, so this should not be considered a proxy for an actual increased reproductive population of the species, and a dedicated sampling effort is desirable to obtain accurate information about the nesting areas of the species [34]. Despite the role of the nesting areas played by Sicily, little is known about the occurrence of feeding areas along the Sicilian coast. As stressed by Blasi et al. [30] and Almpandou et al. [39], some areas around Sicily might constitute foraging habitats for *Caretta caretta*, and this might further expose the animals to serious threats, such as their incidental catch or boat collision.

Most of the available studies on *Caretta caretta* focus on aspects related to the status of the nesting areas [29]; the negative effect of marine pollution on the species [40,41], as well as the occurrence of microplastics and other associated chemicals substances in the gastrointestinal tract of sea turtle [42] and their eggs ([43] and references therein); the community of epibionts [44] and the microbiota [45,46] associated with the species. In addition, a few studies focused on the satellite monitoring of the species aiming to reconstruct their migratory routes (e.g., [47,48]), which include their passage close to the Sicilian coasts. Recently, Abalo-Moral et al. [49] satellite-tracked loggerhead sea turtles in the western Mediterranean area, identifying Sicily as a core area, especially for post-hatchlings, early and post juveniles, stressing how the island seems to be a crucial developmental area for the species.

C. caretta is a charismatic species, protected by international conventions (e.g., Bern Convention, Annex II; Washington Convention—CITES, Annex II) and by European national and regional laws (e.g., Habitat Directive 92/43, Appendices II and IV). IUCN Assessment: “Vulnerable” [20].

The cumulative number of published papers on the species in the last twenty years show a constant and conspicuous research effort from 2006 onwards, making *C. caretta* the most investigated Testudines among those occurring in the study area.

Family Emydidae Rafinesque, 1815.

Genus *Emys* Duméril, 1805.

Emys trinacris Fritz, Fattizzo, Guicking, Tripepi, Pennisi, Lenk, Joger and Wink, 2005—Figure 1B.

Remarks

The Sicilian pond turtle has been the object of several investigations aimed to assess its taxonomical and distributional status, through the implementation of microsatellite loci and sequence data [10,50], and its karyotype has been described [51]. A study by Vamberger et al. [10] revealed a negligible gene flow between *Emys trinacris* and the congeneric *E. orbicularis*, which is widespread in Peninsular Italy and Sardinia, and a strong genetic structuring of the species in five distinct geographical clusters occur on the island [50], suggesting a long presence of the pond turtles in their areas and scarce inter-populations exchanges [10,50,52]. Despite the available genetic evidence, the Societas Europaea Herpetologica’s Taxonomic Committee suggested treating *Emys trinacris* as a subspecies of *E. orbicularis* [53]. Nevertheless, and in accordance with Ottonello et al. [52], taking into account that the Sicilian pond turtle has a genetic divergence from its sister taxon higher than that observed between other accepted emydid species (e.g., within the genus *Graptemys* spp. [54,55]), we here prefer to treat *E. trinacris* as a distinct taxon of species rank.

The endemic Sicilian pond turtle *Emys trinacris* has a wide, but fragmented, distribution on the island (see Figure 10 in [52] and reference therein), which is in part due to its limited dispersal capability [10,56,57]. It is absent from the circum-Sicilian islets [52]. However, the fine-scale distribution of the species is currently doubtful since incomplete

information is available on this matter [57,58]. The species has an altitudinal distribution range from sea level up to 1250 m a.s.l. [52,59].

Unfortunately, *E. trinacris* populations are facing several threats, i.e., habitat loss and fragmentation [10,60–63], invasive alien species [17,21,64–68], and parasite spillover [69–72]. Conversely, recreational fishing seems to have a limited impact on the Sicilian pond turtle [73].

Emys trinacris is included (sub *Emys orbicularis*) in Annex II of the Bern Convention and Appendix II of the Habitat Directive 92/43. IUCN Assessment: “Near Threatened” [18].

The cumulative number of published papers on the species in the last two decades shows a steady and conspicuous research effort from 2003 onwards.

Genus *Trachemys* Agassiz, 1857.

Trachemys scripta (Thunberg in Schoepff, 1792)—Figure 1B.

Remarks

The pond slider *Trachemys scripta* is one of the most widespread species beyond its native distribution range, i.e., the south-eastern United States of America [74]. *Trachemys scripta* is a polytypic species that includes three subspecies, i.e., *T. scripta scripta*, *T. s. elegans*, and *T. s. trostii*, which are all native to North America. All the three currently recognised subspecies can be identified only on morphological bases (e.g., colouration pattern, see [75] and references therein). Due to its commercial interest, the species was imported and released in the wild worldwide, causing negative impacts on native pond turtles, e.g., *Emys orbicularis* (e.g., [62,76]) and other turtle species (e.g., [77]).

To date, in Sicily [26,78], as well as in the rest of the Italian peninsula, the pond slider has a wide, but fragmented, distribution [22,25,79,80]. However, lacking a proper assessment of the species on the island, its actual local distribution is partially unknown. Standfuss et al. [64] and Tietz et al. [81] genetically proved the invasive potential and the successful reproduction of *T. scripta* in Slovenia and Germany, respectively. Evidence of successful reproduction of the pond slider in the Italian peninsula was reviewed by Ficetola et al. [76]; see also [82]. In Sicily, despite the report of a female *T. scripta scripta* laying eggs in “Lago Pergusa” by Liuzzo et al. [65] nothing sure is known about the status and successful reproduction of this invasive species on the island. Recently, Vecchioni et al. [21] found genetic evidence supporting the existence of viable populations of the species in two different permanent water bodies in Sicily, raising concerns about the negative impacts that this emydid could have on the endemic species *Emys trinacris*. Despite this, it is well known that *Trachemys scripta* is a particularly long-lived species [74]; so even if reproduction phenomena were not present in Sicily, released individuals could interact often and for a long time with the native biota, also considering their abundance on the island. However, to date, evidence on the impacts of the pond slider on the Sicilian pond turtle is little (but see [64,76,82]); therefore, further studies should be carried out to ascertain such negative effects on the native biota.

In the late 1990s, the European Union implemented a pet trade regulation banning its importation of it [21], with controversial results (e.g., [83]). Moreover, the ban was bypassed by the market through the import and commercialization of closely related taxa belonging to the genera *Trachemys*, *Graptemys*, and *Pseudemys* (*pers. observ.*)

The first paper dealing with the occurrence of *T. scripta* in Sicily dates back to 2014, although the species was present on the island long before that year, as shown by grey literature and amateur reports (e.g., [80,84]).

Family Testudinidae Batsch, 1788.

Genus *Testudo* Linnaeus, 1758.

Testudo hermanni hermanni Gmelin, 1789—Figure 1C.

Remarks

The Hermann’s tortoise *Testudo hermanni*, which is endemic to the northern Mediterranean area, is a polytypic species including *T. hermanni hermanni* with a western Mediterranean distribution, and *T. h. boettgeri* Mojsisovics, 1889, occurring in the Balkans [85].

Based on mitochondrial markers, Fritz et al. [86] found that studied Sicilian *T. h. hermanni* individuals had the same haplotype occurring in the Corsican and Sardinian populations of the species. Giacalone et al. [87], through an expanded sampling in Sicily, confirmed the widespread occurrence of this haplotype shared with Corsica and Sardinia. Furthermore, the authors hypothesised that after the local extinctions of the Corsican and Sardinian populations, the recolonization of these two Mediterranean islands originated most likely from Sicily (see also [88]). However, based on the microsatellites results, Zenboudji et al. [89] partially rejected the hypothesis of Giacalone et al. [87], stating that Corsican tortoises have an ancient independent origin and can be considered as an autochthonous lineage there, whereas the Sardinian and Sicilian populations belong to the same lineage. In fact, as stated by Zenboudji et al. [89], the high genetic similarity observed between Sardinian and Sicilian *Testudo hermanni hermanni* populations corroborates the hypothesis of extinction of the original lineage in Sardinia followed by a subsequent recolonization from Sicily.

T. hermanni hermanni has an uneven distribution in Italy [22,25], mostly limited to the coastal belt of the peninsula, even if the species can also be found at higher altitudes [22,25,79,85]. In Sicily, the distribution of the species is fragmented and the few populations occurring on the island are considered to be in decline, due to habitat alteration and fragmentation, frequent wildfires, urban development, and agricultural intensification [22,25,79,90,91]. Recently, a restocking project in a *T. h. hermanni* population in a protected area in north-western Sicily was carried out, successfully integrating rescued tortoises [92].

Testudo hermanni hermanni is protected by international conventions (e.g., Bern Convention, annex II; Washington Convention—CITES, Annex II) and by European national and regional laws (e.g., Habitat Directive 92/43, Appendices II and IV). IUCN Assessment: “Near Threatened” [19].

The cumulative number of published papers on the species in the last twenty years shows a slow increase in the number of published papers between 2004 and 2016, with a single further contribution published in the last six years. No further studies on the species are indexed by Scopus.

4. Discussion

The review of the recent (2000–2022) literature dealing with Sicilian Testudines is possibly underestimating the actual research carried out about these taxa since grey literature and books are not indexed by Scopus. However, some trends are quite evident.

The loggerhead sea turtle *Caretta caretta* is by far the most studied Testudines species in the last 20 years, followed by the pond turtle *Emys trinacris*, which has undergone a notable increase in studies in the last decade. Conversely, studies on Herman’s tortoise *Testudo hermanni hermanni* have dramatically declined from 2016 to the present. Finally, based on the bibliographic survey conducted, the non-native emydid species *Trachemys scripta* appears to be relatively little studied. It seems evident that the paucity of studies is not representative of the actual occurrence of the species on the island (cf. [17,93]).

Based on the review of the available data, all the species of Testudines occurring in Sicily showed a fragmented and incompletely known distribution.

With regard to the only sea turtle species considered in this study, i.e., *Caretta caretta*, it is well known that this species resides in our seas [20,22,25,33,94] and regularly exploits the Sicilian coasts to lay eggs [33]; however, the number of nesting sites is currently underestimated [33,95] mainly due to the lack of adequate sampling effort. Currently, based on the efforts made by specialists (i.e., IUCN Marine Turtle Specialist Group) to define the status of *C. caretta* populations and assess their actual conservation status, the species has been categorised as LR–HT (Low Risk–High Threats), meaning that the species has several stable populations in the Mediterranean area but subject to significant threats [95–97].

In Sicily, the large-scale distribution of *Emys trinacris*, ranging from southeast to northwest of the island with some gaps, is relatively well-known, although fine-scale information is missing [52]. While this increase may partially be explained by grown awareness and reporting by citizens, as well as due to the numerous studies that have taken place over the last few decades (see Figure 2), there is no doubt that *Emys trinacris* is the most widespread Testudines species on the island. The species is threatened by several menaces (see above) and by genetic pollution related to the release in the wild of *E. orbicularis* individuals illegally held [98]. In addition, the paucity of demographic information on populations is still a huge shortfall, even in light of the long-term impact of climate change and alien species, including through parasite spillover (e.g., [69,71]).

Regarding *Testudo hermanni hermanni* to date, there are few known viable populations in Sicily [87]; this is probably due to the fragmentation and alteration of suitable habitats for the species, as well as the illegal pet trade, [90,92], which have negatively impacted the species, causing a sharp decline of *T. h. hermanni* populations. Moreover, the picture is further blurred by a relatively low sampling effort and the scarce contactability of the species, as suggested by the small number of papers produced in the last decade in comparison with other Testudines taxa (Figure 2). To date, the knowledge gap regarding the actual distribution and conservation status of this Testudines species is the most worrisome; this is further alarming in light of the genetic evidence [87,89] showing that there is an endemic haplogroup occurring in Sicily and Sardinia.

Regarding the American pond slider *Trachemys scripta*, based on published and unpublished records, the species appears to be widely distributed on the island with numerous groups of individuals, despite little being known about the actual successful breeding of the species in Sicily [21]. However, based on the data reported by Vecchioni et al. [21], the species might find apparently favourable environmental conditions for its development on the island. In addition, reports of new specimens occurring in unknown previous sites are reported daily on amateur blogs or Facebook groups (e.g., “Fauna Siciliana”, <https://www.facebook.com/groups/faunasiciliana/>) and other alien Emydidae (and their hybrids) are increasingly being sighted. This is caused by continuous and frequent uncontrolled releases in the wild of specimens previously kept in captivity. In the light of this, it is evident how it is necessary to carry out careful assessments of the real distribution of the species on the island in order to prevent competition and predation phenomena from further stressing the native populations present on the island, e.g., the native water crab *Potamon fluviatile* (Herbst, 1758) [99,100], as well as the endemic Sicilian pond turtle *Emys trinacris*. When possible, animals should be removed from natural water bodies.

In light of this, increasing environmental education activities, which would empower individuals, groups, and institutions to properly explore ecological issues along with thoughts and activities for native biota sustainability is desirable. As a matter of fact, poor environmental education leads to the constant release, both intentional or not, of allochthonous species in the wild, e.g., among reptiles the brahminy blindsnake, *Indotyphlops braminus* (Daudin, 1803) [101] on the mainland, or *Trachemys scripta* in inland waters [21]. Despite this, their settlement does not always occur, but it is known that an increase in propagule pressure increases the chance that biological invasions will succeed [102].

In addition to the species discussed in the frame of this work, other Testudines have been occasionally reported to occur in Sicily due to erraticism, e.g., *Chelonia mydas* (Linnaeus, 1758) [22,103–105], *Dermochelys coriacea* (Vandelli, 1761) [22,41,105], *Eretmochelys imbricata* (Linnaeus, 1766) [22,25], or due to releases in the wild by amateur breeders (e.g., *Testudo graeca* (Linnaeus, 1758) [26,106,107], and *Testudo marginata* Schoepff, 1792 [108]). However, all of these taxa proved to be so far unable to establish viable populations on the island.

5. Conclusions

The current knowledge of the distribution and status of the Sicilian Testudines taxa is largely incomplete and more dedicated studies should be realised to obtain more detailed knowledge of the actual distribution and biology of the occurring species. Furthermore,

despite being protected by CITES or other conservation programs, these taxa suffer from several threats, which negatively affect their current status. In light of all this, future monitoring programs on the island should be enhanced, with an emphasis on those taxa in decline (e.g., *Testudo hermanni hermanni*) and on invasive species (i.e., non-native emydids), also involving Citizen Science programs, thus facilitating monitoring activities, especially for those difficult-to-reach areas.

In conclusion, Sicilian native Testudines species are mainly threatened by habitat alterations and fragmentations, but a sound assessment is precluded by the insufficiency of available information. In addition, Hermann's tortoise suffers from the direct collection of individuals for amateur purposes and the impacts of wildfires, while the endemic Sicilian pond turtle suffers from competition with allochthonous species, although some of them play ambivalent roles in their diets (e.g., [109]).

Author Contributions: Conceptualization, F.M. and M.A.; methodology, L.V. and F.M.; writing—original draft preparation, L.V., M.V. and F.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the fund “NextGenerationEU” of the European Union (D.M. 737/2021–CUP B79J21038330001).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Enrico Di Girolamo (Figure 1A, *Caretta caretta*) and Domenico Margarese (Figure 1C,D, *Trachemys scripta*, *Emys trinacris*, and *Testudo hermanni hermanni*) are acknowledged for having provided the photos of the Testudines species represented in Figure 1.

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

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