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Occurrence and tentative population status of the Balkan Terrapin (*Mauremys rivulata*, Valenciennes, 1833) on Greek islands

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Abstract

The distribution of *Mauremys rivulata* on Aegean islands was summarized by Broggi in 2012. Here, the study area encompasses all Greek islands, including the Ionian Islands, and the two Turkish islands of Gökceada and Bozcaada. For the first time, I attempt to estimate the status and size of the populations on the islands. This is a subjective assessment based on my personal visits to most islands and not on IUCN criteria. *Mauremys rivulata* was found on 29 Greek islands, plus two Turkish islands in the Aegean Sea. Five previously mentioned sites are doubtful, and on the three islands of Sifnos, Syros and Ithaca the species appears to be extinct. On 12 islands I assess its status as "threatened with extinction". On seven, mostly larger, islands its populations are probably less vulnerable. Efforts must be made for the long-term protection of *M. rivulata* on the Greek islands.

Key Words

conservation, Reptilia, status, Testudines, threats

Species description

The first description of the Balkan Terrapin *Mauremys rivulata* was provided by Valenciennes, on Bory de Saint-Vincent's scientific expedition (1833) to Morea (Peloponnese), under the name *Emys rivulata* (Mantziou and Rifai 2014). In 1913, Siebenrock (1913) split the species into three subspecies. A clear geographical distinction between the former *M. caspica caspica* and *M. caspica rivulata*, and the elevation to species rank, was made by Fritz and Wischuf (1997). This species status was later confirmed by DNA analyses (e.g. Mantziou et al. 2004).

The Balkan Terrapin is an impressive animal, reaching a carapace length of 25 cm, while the 4–10 hatchlings that leave the nest measure 3–4 cm. The species is distributed from the Croatian coast southwards in south-eastern Europe, including Greece, via Turkey to Israel and Syria in the Middle East. It is adapted to a warm Mediterranean climate. In the northern parts of its range it hibernates; while in southern climates it may aestivate over the summer. It occurs in running waters, seasonal ponds and pools, lakes, brackish lagoons, but also drainage systems, e.g. ditches, as well as reservoirs. Only fast-flowing streams are not colonised. The Balkan Terrapin is more tolerant of poor water quality than the European Pond Terrapin (*Emys orbicularis*) which co-occurs in part of the range of *M. rivulata*, and is thus also found in over-fertilised waters or, as mentioned, brackish water.

Due to its tolerance to salinity, the Balkan Terrapin may cross extensive distances at sea, as demonstrated by Vamberger et al. (2014). Since the Asia Minor islands are separated by sea from mainland Anatolia, one would have expected the populations there to have developed differently compared to the Anatolian populations. "The amazing thing is that even turtles that are spatially distant from each other show an almost identical genetic pattern," says

Prof. Uwe Fritz, who was involved in the study (Vamberger et al. 2014). In other species, this could happen when animals are transported by humans intentionally or accidentally. But in the case of the Balkan Terrapin, this explanation is unlikely. *Mauremys rivulata*, unlike the European Pond Terrapin, often empties the contents of its cloaca when captured. Additionally, the unpleasant, musky-smelling secretion it produces is an effective protection. So there was no reason to transport the turtles on a large scale. On the other hand, turtles may be carried into the sea during storms and river floods and some could survive in the sea until they were washed up on a coast again.

Mauremys rivulata does not normally feed at water temperatures below 13 °C. It is a generalist and opportunist, feeding on plants as well as on small animals. It can occur in densities of 19–217 individuals, in eutrophic waters even up to 2000 individuals per hectare (Wischuf and Busack 2001). There are no such high densities on the Greek islands because such extensive habitats do not occur there, but populations of several hundred animals are possible. Populations on small Mediterranean islands, where wetlands are usually small and under heavy human pressure, are usually very vulnerable. This is true for the majority of their occurrences on Greek islands today. As Beutler and Froer (1980) said: "Many island populations are now threatened with extinction."

On the herpetological exploration of the islands

From the early 19th century on, the Greek herpetofauna has fascinated the international research community. The first herpetological "discoverer" was the Russian Jacques von Bedriaga, publishing his work "Die Amphibien und Reptilien Griechenlands" in German (Bedriaga 1883). After the turn of the century, with a peak in the 1930s, the Viennese Professor Franz Werner published 12 articles on the herpetofauna of the Greek islands. He was accompanied and followed by the Viennese Otto Wettstein with "Herpetologia aegaea" in 1953 and a supplement in 1957. This has been described as the "German wave" in herpetological research as far as the language of the written contributions was concerned. Since the early 1970s, the number of field herpetologists working on Greek islands has increased. They are referred to by Pafilis (2010) as the "International Brigade" and included, among others, the Britons Richard Clark and David Buttle. Most of the contributions were made by Augusto Cattaneo from Rome, and the author of this paper from Liechtenstein. Tortoises were not always the primary interest for herpetologists, who often concentrated on lizards and/or snakes. Thus, data on the island herpetofauna for *Mauremys* and *Emys* are rather meagre. For Greece, herpetological checklists were compiled by John Ondrias (Ondrias 1968) and Basil Chondropoulos (Chondropoulos 1986, 1989), but these did not include turtles. In the last 20 years, molecular biology has contributed significantly to further research and allowed the recognition of cryptic species in particular. With the standard work "The Amphibians and Reptiles of Greece" by Valakos et al. (2008), researchers from Greece in particular are taking over the further study of the country's herpetofauna. Our recent knowledge is complemented by numerous European nature photographers who have reported on their travels on various websites and include excellent animal photographs.

Methods: specific procedures for finding *Mauremys rivulata*

The Mediterranean region has been visited annually since 1972 by a group of nature lovers from the Botanical-Zoological Society Liechtenstein-Sargans-Werdenberg from the Alpine Rhine Valley (Table 1). Due to advancing age, the number of excursion participants has decreased from a maximum of 10 to 3. The majority of the 49 excursions to date have taken place on Greek islands, starting in 1975 with Samos. Since 2005, only Greek islands have been visited, a different one every year, and usually for a fortnight. Only the islands of Ikaria, Kythera and Kefalonia have been visited twice so far.

My tasks as excursion leader were island selection, finding literature and, for some time, logistical organisation, which I have since handed over to a colleague. Strikes, strong winds, and Covid-19 have presented logistical challenges. Procuring literature used to be much more difficult before the internet, as the writers came from many states and often used their respective native languages. There was an exchange of writings and experiences, and the number of field herpetologists working on Greek islands was manageable. During the past 20 years, the number of researchers has increased dramatically. Mostly young Greek university graduates have joined, and the language of publication is now predominantly English.

Maps of the islands to be visited were not commercially available in the early days. They were partly hand-drawn and very rudimentary. Today we have suitable GIS-based maps of most (e.g., Anavasi, Skai, Orana, Terrain Map). On them, it is easier to locate hydrological objects with appropriate signatures, such as the indication of springs, permanently flowing watercourses, swamps, lagoons, old water mills, cisterns and wells. Google Maps also provides an overview of hydrological catchment areas with its aerial photographs. The WWF-Greece's Wetland Inventory of the Greek Archipelago is an important reference source (www.oikoskopio.gr/ygrotopio). In addition, the location data from the literature for the water-loving species of the herpetofauna were used. These are all transferred to the maps.

Once we arrived on an island, we first took a tour to familiarise ourselves with the topographical features. Then the objects marked on the map were systematically visited. The hydrologically productive units were verified in the field and searched if the terrain allowed. In the process, there were always opportunities to talk to local people, who usually wanted to know where we came from

Table 1. Dates of excursions to Greek and Turkish Islands. This list includes all the islands visited in the Aegean and Ionian Sea. No Balkan Terrapins were observed on the islands not mentioned in the article.

Samos 12–20.4.1975	Tilos 8–11.10.2004, 15–23.4.2005
Lesbos 9–23.4.1978	Nisyros 24–27.4.2005
Naxos 28.4–4.5.1984	Amorgos 19–28.4.2006
Lefkas 19.5–24.5.1985	Lipsi 10–20.4. 2007
Ikaria 17–30.4.1986	Patmos 17.4.2007
Samothrace 25.4–6.5.1987	Kos 9.4.2007
Rhodes 23.4.1988	Ithaca 15.4–24.4.2008
Karpathos 24.4–6.5.1988	Alonissos 13–25.4.2009
Kythira 30.4–4.5.1989	Serifos 11–19.4.2010
Chios 23.4–3.5.1991	Paros 20.4.2010
Kefalonia 15–23.4.1993	Kea 9–19.4.2011
Andros 8.4–19.4.1995	Crete 10–12.4.2012
Thassos 25–29.5.1996	Gavdos 12–19.4.2012
Kalymnos 19–24.4.1997	Kimolos 5–17.4.2013
Leros 25–28.4.1997	Polyegos 15.4.2013
Kos 19–20.4.1997	Elafonissos 6–14.4.2014
Gökçeada 27.4–7.5.1998	Kythira 6–18.4.2015
Milos 18–24.4.1999, 18.4.2013	Limnos 17–28.2016
Sifnos 25–30.4.1999	Kefalonia 13–26.4.2017
Ikaria 24–4.5.2000	Skopelos 9–15.6.2019
Astypalea 23–29.4.2001	Skiathos 16.6.2019
Symi 23.4–1.5.2002	Kythnos 28.5–8.6. 2021
Sesklia 28.4.2022	Ios 8–17.4.2022
Skyros 19–30.4.2003	Santorini 18–19.4. 2022
	Fourni 14–24.4.2023

and what we were looking for. This was explained in basic terms. In addition, word typically got around on smaller islands about what aspect of the island's natural history these "strangers" were particularly interested in. An island diary was kept, and the geographical information system was used to record the locations and the observations. Towards the end of the island stay, work was already being done on the manuscript for possible publication, so as to record impressions while they were still fresh.

Occurrence of *M. rivulata* on all Greek islands as well as on two Turkish islands in the Aegean Sea (in alphabetical order)

Mauremys rivulata is still found on 29 Greek islands plus on two Turkish islands. Five sites are doubtful and on three islands the species appears to be extinct (Fig. 1). On 12 islands *Mauremys* is threatened with extinction. Only on seven islands its populations are less vulnerable.

Present on island

Andros (380 km^2)

The first record is by Werner (1937). Buttle (1995) includes *Mauremys* for Andros in a species list, without comment. Buttle (1997) states: "Often seen in quite large numbers, especially in still water pools, along the riverine Ateni valley, in hillside streams around Katakilos, and in pools on coastal marshes at the bays of Atemi and Vori."

According to our own experience (Broggi 1996), the Balkan Terrapin occurs in the larger beach lagoons, but in mostly small populations. It migrates sometime up the streams and lives up to its German name "Eastern Mediterranean Stream Turtle". The abundance of water on the island in general, and the scours of the creeks in particular, make it possible for it to survive in isolated populations. Seven location records for *Mauremys* included no more than 20 specimens seen per location (see map in Broggi 1996). The separate populations appear to be stable on the island, especially as the species also inhabits streams (Broggi 1996).

Bozcaada (Tenedos) (37 km^2)

The first record on this Turkish Aegean island comes from Tosunoglu et al. (2009) in a description of the island's herpetofauna. However, only one location is given. Similarly, Gül et al. (2014) write: "Only one freshwater habitat in Lake Azmak; with a fish trap a total of 29 *M. rivulata* were sampled." I have not visited the island personally. Bozcaada is the second smallest island with a *M. rivulata* population. With only one location, the species is threatened.

Chios (843 km^2)

Werner (1935) was the first to describe *M. rivulata* on Chios, followed by Wettstein (1953), and since then its occurrence has been confirmed several times, e.g. in Tsunis and Dimitropoulos (1994), as well as travel descriptions by nature photographers (for example: iNaturalist 2023). In the work on the herpetofauna of Samos and Chios by Cattaneo (2003), however, the species is not mentioned. In my own diary notes for Chios there is only one observation at Kateros, a wetland, with 10 specimens, on 23.4.1991. Thus, it can be stated that the Balkan Terrapin occurs on Chios, but seems not to form large populations. Its status remains to be verified.

Corfu (585 km^2)

First recorded by De Betta (1868), while Werner (1894) also has an early record of *M. rivulata* on the island. Mertens (1961), in particular, dealt intensively with the herpetofauna of Corfu. Buttle (1995) confirms the occurrence: "*Mauremys rivulata* can be found in every gully and lake." In Toth et al. (2002) there is an overview of the occurrence of *M. rivulata* on the island, but without population data. Hill (2003) says: "The two terrapin species could only be found as single individuals." The rarity of both species was striking and contradicts the information of Wütschert (1984), who mentions a wide distribution, with *E. orbicularis* predominating. According to him, the two terrapins can be found in practically

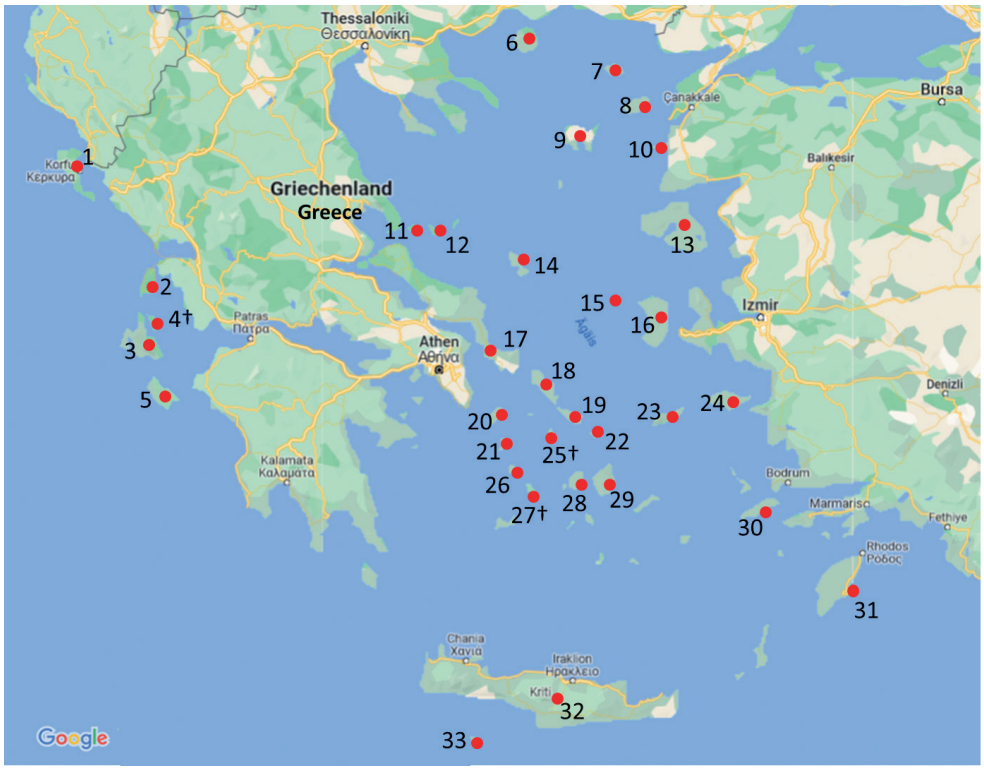

Figure 1. Distribution map of the Balkan Terrapin (*Mauremys rivulata*, Valenciennes, 1833) on Greek islands. Red dot – occurrence, cross – extinct. 1. Corfu; 2. Lefkada; 3. Kefalonia; 4. Ithaca †; 5. Zakynthos; 6. Thassos; 7. Samothrace; 8. Gökçeada (Imbros); 9. Limnos; 10. Bozcaada (Tenedos); 11. Skiathos; 12. Skopelos; 13. Lesbos; 14. Skyros; 15. Psara; 16. Chios; 17. Euböa (Evia); 18. Andros; 19. Tinos; 20. Kea; 21. Kythnos; 22. Mykonos; 23. Ikaria; 24. Samos; 25. Syros †; 26. Serifos; 27. Sifnos †; 28. Paros; 29. Naxos; 30. Kos; 31. Rhodes; 32. Crete; 33. Gavdos.

all watercourses and ponds on the island. Stille et al. (2021) point to an increase in invasive Red-eared Slider Turtles (*Trachemys scripta*).

Crete (8 450 km²)

The first record after Bedriaga (1882) was by Duméril and Bibron (1839). Wettstein (1931) gives an overview of the herpetofauna of Crete. He names five locations, although these held only individual animals. Nevertheless, he thought "that along the whole of Crete in estuaries and marshes the species was widespread". Werner (1938) lists 13 different locations of the species in Crete. In the article by Mantziou and Rifai (2014), the recent known locations are shown on a distribution map. According to this, the species is distributed all over the island. On Crete, there is a chance of encountering the Balkan Terrapin in fresh or brackish water, even in larger aggregations. Nature photographers such as Speybroeck (2009) and others have documented such occurrences in their travel reports. There is also a bibliography of Crete's reptiles by Midtgaard (2019). I was active in Crete for only three days and was unable to gain an overview of the large island.

Euboea (Evia) (3 684 km²)

First mentioned by Cyren (1933). Werner (1938) also reports a record. Pictures of *Mauremys* on Euboea can be found on the internet, for example iNaturalist (2023), taken on April 16, 2022 from the north-east coast of Evia. I do not know the exact status of the species on the island, as so far I have only crossed it to catch the ferry to Kea Island.

Gavdos (33 km²)

Valakos (1987) presented the first record of *M. rivulata* in a short note. He observed four adults and 5–6 juveniles. This is probably the most peripheral locality for this species on the islands, as Gavdos covers only 33 km² and lies 48 km south of Crete, making it the southernmost point in Europe. The stream serving as habitat for *M. rivulata* flows into the sea at Lavrakas and an only partially watered section is found about 1.5 km upstream at the chapel of Agios Georgios. Mantziou and Rifai (2014) estimated the population at 50 animals. It is genetically and morphologically distinct from the Crete populations (Mantziou et al. 2004). We visited the island in April 2012 (Broggi 2014). Only two adults and one sub-adult and later one juvenile specimen were noted in two visits. The geology university professor Apostolos Alexipoulos from Athens, who is familiar with the locality, estimated the population at 10–12 individuals (pers. comm.). This means that there is a great risk of extinction, especially since the stream was already showing signs of drying out in April 2012. The species likely aestivates here.

Gökçeada (Imbros) (279 km²)

First record by Baran (1981). Balik et al. (1993) found five sites for *M. rivulata*. Our visit in 1998 allowed the following observation: The Balkan terrapin occurs at most of the stream estuaries, and migrates up the stream systems (Broggi 1999). One location of animals between two waterfalls was particularly interesting, especially considering the difficulty in accessing it. The paper by Bayrakci et al. (2016) states: "The species is distributed almost all around the island, particularly in the western part, with a low density. The population size in the largest river on the island, Büyükdere, was estimated at 136 individuals." There are, therefore, large occurrences on this island.

Ikaria (255 km²)

First recorded by Broggi (1994). During our excursion in May 1986, 200–300 *M. rivulata* were found at the Misonas estuary near Caliskari, and over 100 at the Charakas River near Armenistis. These are backwaters at the mouths of streams, which are created by the formation of beach walls and form ideal habitats for terrapins (Fig. 2). The turtles also ascend into the streams here, as the example at Charakas showed. For example, *Mauremys* have been observed in a drinking water catchment at Oros Fytron at over 500 metres above sea level (Broggi 1994). Dug, open-water basins are colonised on the mountain plateau. Clark (1996) confirms this for Ikaria as follows: "*Mauremys* was found nearly everywhere – in large congregations in bodies of water behind shorelines and in significantly smaller populations in streams."

Our second visit to the island in 2000 confirmed the wide distribution in the north-west at all altitudes. However, the large populations seem to have halved (Broggi 2001). With this wide distribution in the north-west clear, the species should not yet be endangered as such. Oefinger (2019) reports hand-tame terrapins feeding at the Myrsonas stream on Ikaria in June 2019 (Fig. 3). For his part, Grano (2020) notes at the same site

Figure 2. Ikaria-Armenistis: Due to beach wall formation, the running waters are dammed back and form suitable habitats for the Balkan Terrapin (April 1986).

Figure 3. Peter Oefinger, German herpetologist with a tame *Mauremys rivulata* on Ikaria-Armenistis (13.6.2019).

the invasive Red-Eared Slider Turtle (*Trachemys scripta elegans*), which is occurring on more and more Greek islands and could endanger the native species because of its more pronounced aggressiveness.

Kea (132 km²)

First record by Grillitsch and Tiedemann (1984), of a dense turtle population, including juveniles, in tributary waters at the mouth of the Pisses River. Four offshore sites in the middle and upper reaches of the Mylopotamus are also mentioned: "It is to be expected that such water-rich valleys will in future serve as refuges for threatened coastal populations."

When we visited the island in 2011, the estuary at Pisses was completely occupied by tourist infrastructure and there was no longer any space for *M. rivulata*. However, the manager of our accommodation, the "Red Tractor" in Korissia, told us that there are still Balkan Terrapins in the Mylopotamos valley, which is difficult to access, and that they are periodically washed out to sea during heavy rainfall. During our stay on the island, we were able to find three more occurrences in water-rich valleys away from the estuary (Broggi 2012). Thus, the prediction of Grillitsch and Tiedemann (1984) could come true.

Kefalonia (787 km²)

First recorded by Werner (1894). Wilson (2006) writes: "Unfortunately, however, on Kefallinia its presence may soon become a thing of the past. On this island it was found to be relatively common at only one locality... At this locality about a dozen adults and juveniles were observed. However, like other such habitats throughout Greece they have a tendency of being turned into local rubbish dumps." We visited the island twice, in 1993 and 2017. In 2017, I found *M. rivulata* at five sites on the island, with small populations. The largest population was found in the extensive Livadi Marshes on the Lassi Peninsula (Fig. 4), where dozens of animals were seen

Figure 4. The Livadi Marshes on Kefalonia are the last suitable habitats for the Balkan Terrapin (16.4.2017).

(Broggi 2017b). Based on these observations, the Balkan Terrapin must be considered endangered on the island.

Kos (287 km²)

First recorded by Werner (1902), with later observations by other herpetologists. I was able to do only a one-day tour of the island, in 1988, with a visit to the lagoon of Tigaki, which did not allow for an overview. Buttle (1995) gives Kos as a location in his island species lists without further comment. Cattaneo (2003) in his herpetological island work mentions six sites with rather small populations and a denser occurrence in the marsh at Pythos. Wilson (2015) gives some observations of *M. rivulata* in his herpetological travelogues. Cattaneo (2020) says the populations are declining due to wetland encroachment by land use, tourism and intensive agriculture. Brueckers et al. (2006) suggest that the Red-eared Slider Turtle is already reproducing naturally on Kos and could become a competitor to the native species.

Kythnos (99 km²)

First recorded by Bedriaga (1882). Werner (1935) saw *M. rivulata* at the lagoon near Lutra, as did Wettstein (1953). Grillitsch and Tiedemann (1984) mentioned two sites on the island. Cattaneo (1990) studied the snakes of Kythnos and confirmed an occurrence in Episcopi Bay (pers. comm, 21.2.2020). The three occurrences on the island known from the literature could not be confirmed by us in 2021. On the other hand, we were able to find a small population close to the coast on the basis of information from the WWF wetland inventory (WWF-Greece 2014), as well as a population in a stream near the Chora, acting on information from the landlord of our apartment (cf. distribution map in Broggi 2021). This population, found after a long search, thrives with more than 50 specimens in the discharged wastewater of the Chora and shows once again that the species can also thrive under eutrophic conditions (Fig. 5). This stream, which is fed by sewage, is endangered by the installation of a sewage treatment plant, as paradoxical as this may sound. Occurring in only two localities, however, the species is endangered on the island.

Figure 5. *Mauremys rivulata* in sewage water of the Chora on Kythnos (8.6.2021).

Lefkada (325 km²)

First record by De Betta according to Bedriaga (1882), and cited in Werner (1894). Sindaco (2020) gives a literature checklist of all *M. rivulata* observed on Lefkada (also known as Lefkas). Apollonoi, Nidri and Vadiliki are named as localities. We visited the island in 1985, and individual herpetological observations were noted in Broggi (1994). *Mauremys rivulata* was found at several aquatic sites, especially in water-bearing ditches. The Balkan Terrapin is frequently captured by nature photographers and pictured on websites, such as Schmid (2018) and iNaturalist (2023), with the last picture from Nidri (12.6.22). The Balkan Terrapin does not appear to be threatened in water-rich Lefkada, although there is no record of large populations.

Lemnos (476 km²)

First found by Werner (1930). Schneider's Herpetofauna of the island states: "In almost all water accumulations, even in shallow rivulets, lived large animals whose dorsal carapaces were higher than the water depth" (Schneider 1996). Cattaneo (2001) also says: "Present in most wet places". Strachinis and Roussos (2016) offer the next overview: "Species found at almost all existing wetlands, the largest population being in a pond in the middle of the island, with 350 specimens." Broggi (2017a) confirms 13 of 20 occurrences named in the wetland inventory (WWF-Greece 2014), with coordinates, and indicates two newly found wetland sites. The new discovery at the Moschilos volcanic crater turned out to be the largest previously unknown occurrence in the island's interior with hundreds of specimens: "Lemnos is the turtle island of the Aegean. The populations on Lemnos are among the most numerous in the Aegean."

Lesbos (1 633 km²)

First recorded by Werner (1935). Wettstein (1953) points out the significant size reached by the turtles of Lesbos. Particularly large specimens live in the clear, brackish water of the Gulf of Hiera, in the south-east of the island. Broggi (1978) states: "At the northern end of Geras Bay, in the brackish backwaters, hundreds of terrapins lay crowded together on the shore and on some small islands to sun themselves. Similarly, observations were made in streams." I described the carapace length as up to 30 cm (Broggi 1978). This was an estimate without measuring, as in the literature the lengths are described as being a maximum of 25 cm (Wischuf and Busack 2000). I think, however, that this size could be exceeded here. Wettstein (1953) also speaks of particularly large specimens living in the brackish water of the Gulf of Hiera and describes one as a "giant specimen", but without specifying the size. Sonnenschein (1980) writes: "On sandy shores, where vegetation cannot gain a foothold, numerous terrapins sun themselves. The space is limited, and some of the animals lie on top of each other. If you get closer to them, the dark mass starts to move and they plop into the water. Bog turtles are frequently seen, they inhabit even the smallest water hole; even in brackish waters on the coast they can be met by the hundreds, the European Pond and the Balkan Terrapin." Buttle (1995) also writes: "*Mauremys rivulata* especially numerous on Lesbos in wetlands and streams", while Kasapidis et al. (1996) give only a location with 4 individuals observed, but refer to Tsunis and Dimitropoulos (1994) saying the species is common on the Aegean islands.

On 5.7.2005, a peculiar behaviour of the Balkan Terrapin was observed on the beach of Skala Eressos in the southwest of the island (Gemel et al. 2008): "More than 50 conspicuously large specimens were present in the adjacent lagoon; juveniles were missing. Most of them swam towards the tourists standing at the edge of the lagoon to beg for food. Some even ran to the shore to take food from the tourists' hands." Busack (2009) also mentions the same behaviour. On 24.6.2008, he saw several dozen Balkan Terrapins near a bridge west of Skala Eresou. A bus driver dropped bread into the water, and many turtles came and fought for their share. Uwe Fritz had seen something similar in western Crete, as well as on the southern coast of Turkey. The threat to native populations by a new invasion of the Common Slider (*Trachemys scripta*) is also mentioned for Lesbos (Christopoulos and Levgolis 2022).

Milos (151 km²)

First recorded by Bedriaga (1882). Schweizer (1935), the self-taught "Snake Hansi" from Allschwil (Canton Basel-land) and acquaintance of my father, states: "[*M. rivulata*] is found in large numbers in the pond area of freshwater accumulations on Milos, furthermore I also saw them on the beach in rush-covered, salty marsh ponds". Werner (1938) and Wettstein (1953) mention the island in their works. Pérez Mellado et al. (1999) found only one specimen at each of two sites on the island, Adamas and Alytes. Broggi (2000) also found two sites on the island and saw only one and three specimens, similar to Speybroeck (2006, 2013). Schweiger (2020) states: "Quite a common sight in Lake Provatas in the 1970s. Completely disappeared due to draining." Obviously, the habitats are dwindling rapidly. *Mauremys rivulata* is endangered on Milos.

Mykonos (105 km²)

First recorded by Bedriaga (1882). The species is later mentioned several times as occurring on Mykonos, but seems to be cited only from older sources. Not so by Wettstein (1953), who visited the island and found *M. rivulata* there. Beutler and Froer (1980) give two sites on the island, but note that one is already largely destroyed. The number of animals at Ftelia was estimated at 100 specimens, which was recorded on 30.5.1977. They are considered to be critically endangered by Beutler and

Froer (1980). That the species still exists on Mykonos is confirmed by a recent photographic travel report by Wilson (2022) from the Cyclades in 2022: "Terrapin in particular seem to be an endangered species in the Cyclades in general, seen at Mykonos." So *M. rivulata* still exists on Mykonos but seems to be endangered by extinction. Personally, I have never been to Mykonos.

Naxos (389 km²)

First record by Werner (1899), mentioning the species for Naxos without further comment as follows: *Clemmys caspica G.* var. *rivulata* Val. In his monograph Werner (1938) does not mention his previous work under the species description. Wettstein (1957) writes: "Not rare on Naxos in small streams in small populations." Buttle (1993), for his part, observes two adult specimens in a drying watercourse. Oefner (2016) observes: "South coast some very shy *Mauremys* and 1 juvenile *M.*, Potamia Valley." A student at the university of Copenhagen wrote to me on 14.4.2022, saying: "Large population in Galanthis Bay, south end of Naxos." We were on Naxos for a week in April 1984 and encountered *Mauremys* eight times in the estuaries of watercourses and in streams (stream SW bay of Appollones, end of stream Myloperama, beach of Galini Ormos Amyti, end of stream Pyrgaki, lagoon Aghiason, stream Potame, lagoons behind Ormos Kalandou, stream after Kouronochori, direction Galini, nearby lagoon Alikes). *Mauremys rivulata* seems to be common on the island in the lower reaches of streams.

Paros (193 km²)

Werner (1938) and Wettstein (1953) do not mention *M. rivulata* for Paros. Gruber and Fuchs (1977) give the following mention as first recorders: "It seems to be rare on Paros in general. We found our specimen in a slow-flowing, muddy stream near Naoussa." Buttle (1995) does not mention it on his species list for Paros, or describes it as "absent". We were on the island for one day that allowed us to get an overview of the landscape. We were shocked by the degree of overdevelopment on the island and have so far refrained from a natural history excursion there. Troidl and Troidl (2021) describe the Balkan Terrapin as the most endangered reptile on the island: "According to our research, and also according to the statements of Johannes Foufopoulos, these animals only occur in a very small area of a temporary stream in the north of Paros." There is talk of a population of 8–12 animals at two water points 150 metres apart. This means that the Balkan terrapin must be described as threatened with extinction on Paros.

Psara (44 km²)

Pafilis et al. (2018) report a record on the island, finding 3 specimens of *M. rivulata* in smaller areas of water near Xirolambos. Psara is isolated, 22 km west of Chios. How is settlement at all possible under the given suboptimal conditions? Transoceanic dispersal must be expected here. "We assume that from time to time turtles are swept out by storms and drifted away by sea currents" (Vamberger et al. 2014). Will the species be able to survive on the island under these conditions, considering there are probably no other suitable habitats available? This is the most unusual record in recent decades.

Rhodes (1 401 km²)

First recorded by Calabresi (1923). Not listed by Werner (1938), but Calabresi's record was included by Wettstein (1953). Wettstein (1965) later reports three specimens taken from the "Seven Springs", noting that he had already seen the species in 1935 in a pond near Apolon on Rhodes. Furthermore, he wrote in 1953: "Not less rare on Rhodes than on Crete." Bader et al. (2009) give an overview and write: "We think that the Balkan Terrapin populates most rivers and streams on the island." They give 12 locations in a distribution map (Fig. 2 there). INaturalist (2023) mention 14 objects on the island with *M.rivulata* observations. Among them are also some occurrences in streams. However, there is no mention of larger populations. Nevertheless, the species seems to be widespread on the island. In 1988 we took only a one-day trip to get an idea of the landscapes.

Samos (477 km²)

First recorded by Werner (1935). The first natural history excursion to a Greek island took us to Samos in April 1975. I likely saw in the distance both species of terrapin at the archaeological site of the Temple of Hera, but I could not confirm this, as, at a time of political tension between Turkey and Greece, we were expelled by the local military and had some problems with our cameras and binoculars and we were forced to hand in slide films.

The island of Samos has been herpetologically studied several times, by Ioannidis et al. (1994), Cattaneo (2003, 2019) and Speybroeck et al. (2019). Speybroeck et al. (2019) give 68 records for *M. rivulata*, found within 3.5% of all grid cells (1 × 1 km) on Samos: "The species seems largely restricted to the south-eastern wetland areas of the island. Single record from the north-western coast near Karlovasi. A relatively high tolerance for elevated levels of salinity and eutrophication." The Balkan Terrapin penetrates streams up to 400 metres above sea level.

The island has been visited by several nature photographers, such as Bok (2009). In his Field Report from October 2009 he writes: "In the dried riverbed of the river Imvrassos, Balkan Terrapins were quite common though the river was reduced to small, shallow pools." Samos, therefore, seems still to have secure populations of *M. rivulata.*

Samothrace (178 km²)

First found by Werner (1935). Wettstein (1953) also mentions the species. We visited the island for the first time

in 1986 in a two-week stay (Broggi 1988), and from then on we took two weeks for each of these island visits. The Balkan Terrapin was observed in small populations at two lower reaches of creeks dammed by beach riprap and three pools along the north coast road. Buttle (1989) also mentions *M. rivulata* from Samothrace. Cattaneo (2001) reports them in good numbers along the creeks, including some backwaters along the beach. Ochsenhofer (2012) names *M. rivulata* as the most common reptile observed, with 10 individuals sighted behind beach walls in impounded estuaries and smaller wetlands. Zagoris (2014) found a new site with *M. rivulata* at Polypoudi in Alonia village. There are, then, multiple populations without larger aggregations on Samothrace.

Serifos (75 km²)

First recorded by Bedriaga (1882). Werner (1933) confirms the record and states: "I found a juvenile in the shore marshes on Seriphos and received two more from there. The species is very common here, for towards the end of my stay I was offered another number." Cattaneo (1980) confirms the occurrence without naming a place. He later names occurrences at two sites, one on a stream through Livadi and the other on the Potamia stream below the village of Potamia in the north of the island, as a result of a personal communication with me on 8.6. 2010. Our excursion in 2010 yielded four more site records. The unused Steno reservoir, still full of water, forms one of the refuges for *M. rivulata* (Broggi 2011). Thus, the species is currently still secure on Serifos.

Skiathos (49 km²)

Bergmann (1995) reports news on the herpetofauna of Skiathos, but nothing on the Balkan Terrapin. First recorded by Cattaneo (1997), who refers to an observed specimen with a length of 16.6 cm, from a small ditch together with green frogs. He writes in Italian, the English translation of which reads: "Because of the progressive extinction of wetlands, all associated species, especially the Balkan Terrapins, are threatened with extinction." I was on Skiathos for only one day in 2019 on my way back from Skopelos. I expected to see *M. rivulata* in the lagoon behind Koukounari beach but did not. In the northern part of the island I heard green frogs calling but saw no terrapins there either. Whether there are any left on Skiathos is questionable. Tourist development is well-advanced on the island, which is only 49 km² in size. One must reckon with the extinction of the species on Skiathos as well as on Skopelos.

Skopelos (96 km²)

First recorded by Cattaneo (1998) – a few specimens in a backwater, including juveniles. As on Skiathos, he considers *M. rivulata* to be threatened with extinction. I visited the island for a week in June 2019. The WWF Greece inventory of island wetlands (WWF Greece 2014) indicates three sites, two of which were still present. An artificially created pond near Lautsa is said to have been home to the Balkan Terrapin a short time ago, according to an internet blog (skopelosculture.org 2011). Despite two visits, I did not see any animals there. Behind Panormos beach, a backwater has been preserved in a depression in the sandy area, and an adult specimen was observed there. Thus, any further occurrence on Skopelos should be assessed very critically.

Skyros (209 km²)

First recorded by Werner (1930). Cattaneo (1998) observed a few specimens in the final section of a stream before it flows into the sea. Our excursion to Skyros took place in 2003 (Broggi 2006a). I noted three occurrences on the Kephisos stream, with about 25 individuals. In another stream, which flows into the bay of Aberounes and creates a backwater due to the formation of beach walls, a few *M. rivulata* were found. Overall, the population on the island is endangered. The alluvial plain of Kalamatsa, covering about 70 ha, is the largest wetland on the island worthy of protection. Agricultural intensification, with drainage, is threatening the habitat there.

Thassos (380 km²)

First reported by Cyren (1933). Buttle (1995) includes it in his species list for Thassos, without comment. Clark (1993, 1999) mentions *M. rivulata* but also does not comment. Cattaneo (2001) saw them in the locality of Prinos, where he noted various specimens. Searching for "Thassos *Mauremys rivulata*"on Google gives an overview of a Natural History of Thassos, including *Mauremys* (Fowles 2001). I was on the island for a week in 1996, but the herpetological results were not sufficient for publication. I did encounter *M. rivulata* on the island at that time in Skala Prinos and Skala Panagia. The population status is not known sufficiently and thus can only be described as occurring.

Tinos (194 km²)

First recorded by Bedriaga (1882). Werner (1938) puts the species on his island list, as does Wettstein (1953). Beutler and Froer (1980) write: "It was probably the best preserved wetland in the Northern Cyclades, the lagoon of Kolibithra. There is another lagoon near Ormos Panormou. Smaller ponds were found around Tinos town, Tripotamos, Kardiani and Isternia." Bohlmann et al (1981) mention only one specimen, near Panormos, in their herpetological notes. Broggi (2019) benefits from using the wetland inventory of WWF-Greece (2014) in his research. The recorded significant habitat of Agios Ioanni no longer exists, as is the case with other, smaller wetlands near the island's capital. All these sites have been searched. The large *Mauremys* populations of Panormou and Kolibithra can be

confirmed. In Broggi (2019), Fig. 3 gives an overview of all recorded occurrences on the island. The Livadi Valley sightings were the largest stream occurrences on a Greek island to date. The Tinos populations are, therefore, still viable.

Zakynthos (406 km²)

First recorded by Werner (1894). Keymar (1986, 1988) dealt with amphibians and reptiles of the Ionian Islands but recorded *M. rivulata* only in the species lists, including for Zakynthos, without comment. This also applies to Buttle (1995), who recorded the species in his list for Zakynthos. Wilson (2006) writes: "It was found to be abundant in the rivers of Limni Keri, and a specimen was also seen in the Laganas river." Wilson (2009) also records two population sizes for Zakynthos in his observations: "5.5.2005, 10 specimens, and 6.9.2009, 20 specimens. He sees an "overpopulation" of *Emys orbicularis* in Lake Keri, including *M. rivulata*. We have not yet visited the island.

Extinct

Ithaca † (118 km²)

Keymar (1986) refers to Cyren (1935) in his herpetological survey of the Ionian Islands. He sighted water turtles in a well in Ithaca but was unable to identify the species. Keymar said this was all the more remarkable because Ithaca had no permanent open water. Cisterns were probably the last habitat refuges of amphibians and hydrophilic reptiles that colonised the archipelago during a "wetter" geological period. Broggi (2009) confirms that there are no suitable habitats for aquatic turtles today. If Cyren's (1935) observation is correct, *M. rivulata*, which has fewer habitat requirements than *Emys orbicularis*, would be extinct.

Sifnos † (74 km²)

Erhard (1858), the first who described the species from Sifnos, wrote that *Mauremys* populations were rare in the wetlands. The species was later reported there by Bedriaga (1882), Werner (1933) and Schweizer (1938). Wettstein (1953) was the last to record two specimens. Grillitsch and Tiedemann (1984) and Broggi (2000) saw no specimens, even in the inland waterholes that had *Pelophylax kurtmuelleri*. Toth (2001) also did not report the species. The once-secure site in the coastal marshes of Kamares has been destroyed by tourist use. Wilson (2022) writes in his blog: "The Balkan Terrapin is probably extinct now that the coastal wetland at Kamares no longer exists."

Syros † (102 km²)

First recorded by Bedriaga in 1882. Werner (1938) refers to Bedriaga in his island list, and no record has been made later. Beutler and Froer (1980) believe the Balkan Terrapin was probably extinct here. Dimitropoulos (2016) has nothing new to report on this either. It must be assumed that the species is extinct, as it is on Sifnos.

Absent / status unknown

Amorgos? (126 km²)

Erhard (1858) mentions the Balkan Terrapin, and Bird (1935) repeats this information. Werner (1938) no longer mentions it, however. Old data may be based on confusion of islands, or the species may have disappeared early. Lotze (1979) dealt with the herpetofauna of Amorgos but could not confirm this species there and thought that suitable habitats were missing. This was confirmed by me after a visit to the island (Broggi 2007).

Chalki? (27 km²)

Grano and Cattaneo (2017) report an observation of a well-preserved dead specimen of *M. rivulata*. They found it on the Dodecanese island of Chalki, near Rhodes, in a dried-up well. This observation requires further clarification. Is it a specimen that was washed here from another island? According to studies by Vamberger et al. (2014), this must be assumed as probable. Suitable habitats are likely to be lacking on the island.

Kythera? (278 km²)

So far, *M. rivulata* has not been recorded here, although Pieper (1970) does not rule out its occurrence. I have been on the island twice, in 1989 and 2015, and think Kythera offers potential habitats for the species, especially in the north of the island and in the beach lagoon of Kakia Lagada. Stavros Emmanuel, a local biologist, said a friend of his had seen terrapins in the Karavas area in the north of the island. My search was in vain, but this is something to keep in mind.

Symi? (58 km²)

Dimaki (2002) mentions *M. rivulata* for Symi, without giving any further location. I could not confirm this on my visit to the island (Broggi 2002), nor could Cattaneo (2007), Wilson and Grillitsch (2009) and Wilson (2012). It must be a case of mistaken identity, since with the exception of a pond, suitable habitats are scarcely present here.

Tilos? (61 km²)

There are no historical records for Tilos. When I visited the island, an adult *M. rivulata* was seen in a water reservoir covered with rubber sheeting south of Megali Chori on 18.4.2005 and subsequent days. There used to be two wetlands on the island, which no longer exist. As a result,

the green frog has become extinct. Is this observation a release or a relict? The present situation is not suitable for the species to persist (Broggi 2006b).

Discussion

Faunistic aspects and occurrence

My favourite observations on the Greek islands for the last three decades have been of terrapins in their habitats. These possible habitats are consistently searched on every island visited. With experience, it is possible to spot the shy animals in their sunny positions from afar. The distribution of the Balkan Terrapin (*Mauremys rivulata*) in the Aegean Sea was described in the journal Herpetozoa (Broggi 2012), and here the statements are updated on the basis of new findings, with the Ionian Islands now taken into account. For the first time, the focus is on population sizes.

In the Aegean and Ionian Islands, *M. rivulata* has been recorded on 29 Greek and two Turkish islands. Five further occurrences are described as questionable, with two of them probably due to misinformation; one of them has potential but remains without confirmed evidence; one refers to a dead deposit; and one is probably due to a release. On Syros, Sifnos and probably Ithaca it can now be assumed that the Balkan Terrapin is extinct. Population sizes appear to be small on most Greek islands but can only be based on estimates. Only from Samos counts are available (Speybroeck et al. 2019). Of all the islands mentioned as having *M. rivulata* present, I have no personal experience of Bozcaada, Corfu, Mykonos, Psara, Syros and Zakynthos.

Wettstein (1953, p.660) writes that "*Clemmys caspica rivulata*" occurs on all larger water-bearing Aegean islands. This statement is still valid, but with limitations. The recent record of the species presented here now includes 29 Greek and two Turkish islands. These occurrences refer to islands covering more than 50 km^2 of land area, except for Gavdos (33 km^2), Bozcaada (37 km^2), Psara (44 km^2) and Skiathos (49 km^2). This is understandable, as it usually takes a larger land mass to form surface waters. In presenting the distribution and assessing the populations, it was possible to draw on our own observations in many cases, as so far around 60 Greek islands have been visited during the last decades (see Table 1).

The Mid-Aegean Trench (MAT) from Crete to Thassos created a sea barrier in the Aegean Sea. Except for sea turtles, *Mauremys rivulata* is the only local reptile species for which the MAT is practically non-existent. Just being a Terrapin is not sufficient to overlook the sea as a barrier. The pattern of occurrence of *Emys orbicularis* is contrary and more similar to the other reptiles and amphibians (Lymberakis and Poulakakis 2010). The optimal habitats of *M. rivulata* are in the estuaries of flowing waters and the beach lagoons that may have formed there. The turtle benefits from the formation of beach walls, which block the outflow of freshwater into the sea by means of currents and backwater, especially when the freshwater pressure towards the sea decreases. Especially in sandy bays, this backwater effect can lead to prolonged water accumulations up to lagoon size. Werner (1935) described this situation with the following statement: "On Sifnos and Samothraki they live in a pool formed at the end of a stream which fails to reach the sea but rather builds up and spreads out on the sandy beach." The largest and particularly impressive populations are thus found in intact lower reaches and in the estuaries of watercourses, as seen on Lesbos in the Gulf of Hiera and at Mirsonas and Charakas on Ikaria.

On vulnerabilities and protection

Substantial threats to *M. rivulata* also exist in other regions of Greece, see Walters (1998) and Erzenberger (2018). The dependence on hydrological phenomena shows the danger and vulnerability on the islands due to land-use conflicts. Tourist development, in particular, is taking place on the sandy beaches that are less common here. Such bays are still being redeveloped and the hydrological systems destroyed, as last seen in 2022 on Ios at Pappa Aulaki Bay, where a backwater was destroyed for a luxury hotel development. The flat areas of the estuaries are also of interest for agriculture. For this purpose, the terrain is levelled, the watercourse is narrowed and thus the possibility of egg-laying is also impaired. In addition, water is taken from the water-holding streams over long distances (Fig. 6). Increasingly, groundwater pumps are also used to lower the groundwater level, with a corresponding impact on the surrounding area.

In sections where there is still a long period of water retention in the watercourse, and the water in scours is retained for longer, refugial populations of *M. rivulata* can settle best. I have noticed such stream colonisations away from the estuary in Thassos, Samothrace, Andros, Lemnos, Kythnos, Kea and Serifos. But even in these more favourable conditions, water is being extracted for agriculture, accelerating their drying out. In addition, most of

Figure 6. Water abstraction for agriculture endangers the habitats of the Balkan Terrapin (Limnos, April 2016).

Figure 7. Open well on Kea (2011).

the natural springs are exploited. The Balkan Terrapin can also resort to using anthropogenic water accumulations such as open cisterns and sites for livestock watering (Fig. 7). However, such artificial biotopes are becoming rarer. They are replaced by closed cisterns and groundwater pumps, and the once-open waterholes for amphibians and hydrophilic reptiles are no longer maintained. The loss of open water areas is also exacerbated by ongoing climate change. In the last two decades, drying out has intensified (Fig. 6). For example, on some islands such as Lipsi, Fourni, Ithaca or Alonissos, no flowing water could be seen from April onwards. On the other hand, winter flash floods can carry turtles all the way into the sea and thus endanger their populations, as experienced in Kea (Broggi 2012). If turtles wash up in new areas, the probability of finding suitable habitats is extremely low.

For *M. rivulata*, there are no sufficient temporal data of its distribution on Greek islands with population estimates. My assessment of the endangerment status therefore does not follow the IUCN criteria for Red Lists of threatened and rare species. These are my personal subjective assessments based on visits to the islands. However, I have been systematically searching Greek islands for *Mauremys* occurrences for the last 30 years. Some of my observations are older, however, and a lot may have happened at the individual sites in the meantime. The threat to the species on Greek islands is generally considered to be high. The current occurrences are highly isolated and exchange with other populations is becoming increasingly difficult. Habitat destruction, but also climate fluctuations, can accelerate extinction. On 12 islands, namely Skyros, Skopelos, Skiathos, Psara, Paros, Mykonos, Milos, Kythnos, Kefalonia, Zakynthos, Gavdos and Bozcaada, the status "threatened with extinction" is appropriate. The status of some other islands is not yet known well-enough to make an assessment. On the other hand, larger confirmed occurrences are found on Gökçeada, Crete, Ikaria, Lemnos, Lesvos, Samos and Tinos. On some of these islands, populations are also found in streams, where they are more protected from threats.

The EU lists *M. rivulata* in Annexes II and IV of the Habitats Directive. It is a species in need of strict protection. Under Greek law (Presidential Decree 67/1981) the Balkan Terrapin is a protected species. It is also listed in the Red List of Threatened Animals of Greece (Legakis and Maragos 2009).

The causes of threats have been presented. It is no longer possible to determine how many wetlands were destroyed in the last century, but a large number of small biotopes were likely affected. Catsadorakis and Paragamian (2007) started in 2004 by compiling an inventory of wetlands for the Aegean islands, excluding Crete. They recorded 352 wetlands, including lagoons, on 51 islands, that covered about 40 km^2. The inventory was subsequently extended to the entire Greek archipelago (WWF Greece 2014; oikoskopio.gr/ygrotopio). Thus, 824 wetland structures were identified on 76 islands, of which 100 were wetlands on Ionian islands, with 526 sites on 64 Aegean islands and 192 on Crete. In a presidential act of June 2012, 350 natural wetlands on 58 islands were strictly protected. Protection is now said to have been extended to 565 wetlands, accounting for 70% of the recorded inventory (Paragamian et al. 2014). Monitoring of the conservation status is recommended.

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