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Combining Monitoring Approaches as a Tool to Assess the Occurrence of the Mediterranean Monk Seal in Samos Island, Greece

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Abstract: With a current global estimation of 600–700 individuals, *Monachus monachus* is considered among the most threatened seal species globally and is ranked as “Endangered” by the IUCN Red List of Threatened Species. The Mediterranean distribution of the species is fragmented, and the largest known sub-population inhabits its easternmost areas. The present study analyses the occurrence of *M. monachus* on Samos Island, in the north-eastern Aegean Sea, Greece. From May 2017 to November 2019, data were collected through a combination of monitoring approaches, including visual monitoring from a land position, opportunistic sightings collected by citizen science, and data of stranded individuals. Results indicate the constant occurrence of monk seals in the waters and coastal areas of Samos Island, confirming the importance of this area for conservation purposes. Furthermore, the results show that an integrated methodological approach can contribute to enhancing and increasing data collection, representing an effective method for conservation studies. This approach could be applied in other locations, allowing the scientific community to identify regions of interest, where to expand targeted monitoring and apply conservation measures.

Keywords: *Monachus monachus*; endangered species; marine mammal; conservation; multi-approaches

1. Introduction

Historically, the distribution range of the Mediterranean monk seal (*Monachus monachus*, Hermann, 1779) extended widely throughout the Mediterranean Sea, the Black Sea, and the North Atlantic Ocean [1]. In the last century, the population has dramatically declined, with a global estimation of 600–700 individuals, of which 350–450 are mature [2]. The species' global population is currently fragmented into three to four definite sub-populations, two located in the Atlantic Ocean (Cabo Blanco and Madeira Archipelagos), one in the Eastern Mediterranean Sea (Greece, Turkey) where the population comprises 300–400 individuals living in Greece [3,4], and about 100 individuals inhabiting Turkey [5].

Over the years, monk seal habitat has changed due to population decline and disturbance-related displacement. While until the 20th century the colonies of Mediterranean monk seals congregated, gave birth, moulted and sought haul-out sites on open beaches [6,7], in more recent years, it has become rare to spot them in their former habitat, and more frequent sightings occur along remote coastlines and caves inaccessible to humans [8].

The Mediterranean monk seal is one of the most evolutionarily distinct and globally endangered (EDGE) mammals [9]. Currently, it is mainly threatened by the deterioration and alteration of its suitable habitats, increase in coastal anthropic disturbance, interaction with fishing activities and gears and overfishing of stocks of its prey [1]. Moreover, the intentional killing of monk seals has in the past caused decline of the species, especially in Greece [10] and in Turkey [5], where it is still a worrying issue.

This protected species was previously classified as “Critically Endangered” by the IUCN Red List of Threatened Species [11] but is now ranked as “Endangered” [2]. Despite action plans for the conservation of the species having been implemented with varying degrees of vigour and commitment in many areas where the presence of the species is known [12], consistent data in areas where its presence and distribution has been recently reported are lacking. This is mainly due to the elusive habits of the species and to the gradual displacement towards habitats that are marginal or inaccessible to humans (e.g., smaller marine caves), as is well-documented in the literature [6,13,14]. In the Aegean archipelago, the morphological characteristics of the coasts and the great number of islands and islets, over 7500 [15], make the development of monitoring activities even more difficult. Furthermore, traditional methods, such as the systematic monitoring of caves, where the occurrence of monk seals has already been reported in the past [13], do not provide enough data to evaluate the recent occurrence of the species in the region over a wide spatial and temporal range.

This study aims to fill the knowledge gap regarding this species, providing recent monk seal occurrence records in the Greek waters surrounding the island of Samos, in the north-eastern Aegean Sea. Multiple methods were employed and tested to monitor monk seal presence. These methods entailed a combination of land-based monitoring surveys, citizen science, and stranding records. The effectiveness of this integrated approach for identifying potential regions of interest to target further monitoring and protection actions is discussed.

2. Materials and Methods

2.1. Study Area

Samos is a Greek island located in the north-eastern Aegean Sea and is separated from the coast of Asia Minor by the 1.6 km wide Mycale Strait in the Central Aegean. The southern coastline is primarily characterized by the presence of cliffs situated between stony and sandy beaches. The northern, eastern, and western sides of the island are dominated by a mixture of rocky shores, cliffs, and stretches of stony beaches. Samos’ distinctive coastline is also characterised by numerous marine caves [16].

Samos Island has been a priority site for the monk seal since 1980 [17] and the north-western region of the island is under strict protection for monk seal conservation (Presidential Decree 100/27-2-1995). The island is located within the Central Aegean Important Marine Mammal Area (IMMA), which is identified as an area of importance for the Mediterranean monk seal [18]. The IMMA also includes the Mycale Strait, which separates Mykali Bay in Samos from the Turkish Dilek Peninsula-Büyük Menderes Delta National Park.

2.2. Land-Based Surveys

From August 2017 to November 2019, systematic land-based surveys were carried out from a fixed land station located on Mykali beach. The monitoring location was selected because of its geographical position, overlooking Mycale Bay and Strait, and due to several monk seal sightings previously reported in the area by local citizens to the researchers. The Mykali stony beach is approximately 2 km long, with a width ranging from 2 to 50 m. A free 125° horizon allowed observations with the naked eye and binoculars (7 × 50) over the bay and the strait. A continuous scan of the sea surface by two observers was carried out for a minimum duration of two hours, from 07:00 to 19:00, to detect monk seal presence. Once detected, the distance of monk seals from the shore was estimated employing a binocular with reticules and recorded in a dedicated datasheet. Data on behavioural states were gathered with a focal ad libitum sampling method [19], employing an ethogram developed for the harbour seal (*Phoca vitulina*) adapted for monk seal behaviours observed in the field (Table 1).

Table 1. Monk seal ethogram [20,21].

Behavioural State	Description	References
Swimming with head above water	The seal actively swims with head (partly) above the water.	Stevens et al., 2013
Scanning the environment	The seal hangs vertically in the water with the head above the water, clearly scanning the environment by looking around.	Stevens et al., 2013
Spot feeding	The seal dives continuously in the same location close to shore for up to several hours, spending up to 12 min underwater, and up to one minute on the surface before initiating the next dive.	Costa Neves, 1998
Transit feeding	The seal covers considerable distances along the shoreline, with dive durations up to seven minutes, before resurfacing.	Costa Neves, 1998

The monitoring activity was conducted with wind force and sea state equal to or lower than level 3 of the Beaufort and Douglas scale. When possible, the observations were supported by the collection of photographs to identify specific individuals and their sex.

The sighting frequency (number of sightings/hours of effort) was calculated and compared between years (2017, 2018, 2019), seasons (winter, spring, summer, fall), and four daily periods (I = 07:00–10:00; II = 10:00–13:00; III = 13:00–16:00; IV = 16:00–19:00) using the Kruskal–Wallis Test. The mean latency among sightings at the Mykali area was also calculated to evaluate the extent of monk seal residency in the investigated area.

2.3. Opportunistic Sightings and Stranding Records

In the same period, opportunistic monitoring was conducted to record the presence of live and stranded individuals around Samos Island's coastline by researchers employed in monitoring activities of the coastal ecosystem. Citizen science was also employed to collect useful information for the assessment of the monk seal's local population status [1,22]. Such information was typically reported by local and port authorities, provided by citizens and tourists, or through social media platforms. The reports were confirmed by the researchers contacting the reporters to evaluate the information and documents provided. When the information and materials allowed, the reports were recorded, and the individual characteristics classified according to Samaranch and González [23]. Regarding stranded individuals, an external examination of the carcass was conducted to assess human-interaction evidence according to Moore et al. [24].

3. Results

The map of sightings and strandings is illustrated in Figure 1.

3.1. Land-Based Surveys

A total of 636 surveys, equating to 1640 h of monitoring activity, were carried out from August 2017 to November 2019 in the Mykali area. During this period, 11 sightings were recorded, with a 0.008 mean sighting frequency (N. sight/hour). Monk seal mean sighting frequency in Mykali varied significantly among years (Kruskal–Wallis Test, $X^2 = 10.05$; $p < 0.05$). However, the sighting frequency was similar for 2017 (0.015) and 2018 (0.013) but in 2019 showed a lower value (0.001) despite the increased number of monitoring efforts (Table 2).

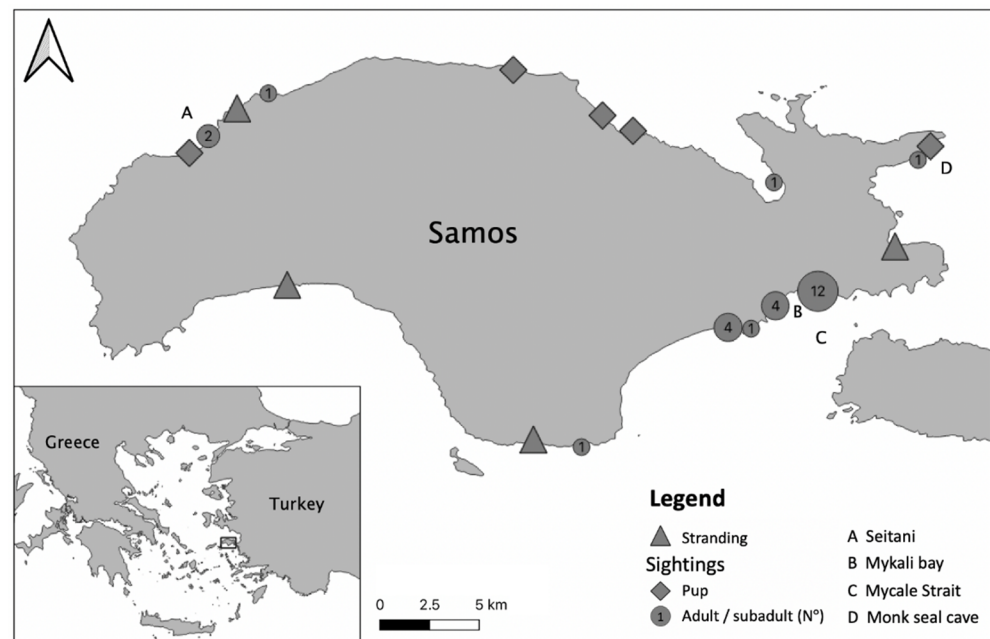


Figure 1. Map of Samos Island with the locations and number of the sightings (land-based and opportunistic) and strandings of monk seals recorded between 2017 and 2019.

Table 2. Survey effort and monk seal mean sighting frequency during the dedicated land-based surveys conducted between August 2017 and November 2019. * Significantly different (Kruskal–Wallis test, $p < 0.05$).

Year	Monitoring Activity		Monk Seal Presence	
	Number of Surveys	Hours	Number Sights	Mean Sight Frequency
2017	34	128	2	0.015
2018	264	601	8	0.013
2019	338	911	1	0.001 *
All periods	636	1640	11	0.008

An analysis of seasonality highlighted a greater mean sighting frequency during the winter (0.011 sightings/hour), compared to the spring (0.007 sightings/hour) and summer (0.007 sightings/hour). No sightings were recorded during the fall season (Table 3). This seasonal difference varied within the years of study although not significantly (Kruskall–Wallis Test, $X^2 = 7.61$; $p = 0.055$).

Table 3. Survey effort per season and correlated monk seal mean sighting frequency. Y: year; N.: number of surveys; H: hours; N.S.: number of sightings; M.: mean sighting frequency.

Y	Winter				Spring				Summer				Fall			
	N.	H.	N.S.	M.	N.	H.	N.S.	M.	N.	H.	N.S.	M.	N.	H.	N.S.	M.
2017	2	6	0	0	NA	NA	NA	NA	21	84	2	0.024	11	38	0	0
2018	14	35	2	0.013	49	120	6	0.059	106	250	0	0	95	196	0	0
2019	103	261	1	0.005	111	315	0	0	93	245	0	0	31	90	0	0
All periods	119	302	3	0.011	160	435	6	0.007	220	579	2	0.007	137	324	0	0

The mean sighting frequency was also analysed in relation to the four daily time periods. The statistical analysis highlighted a significantly greater mean sighting frequency for the second time slot (0.025 sightings/hour), followed by the third (0.011 sightings/hour) and the first (0.002 sightings/hour) (Kruskall–Wallis Test, $X^2 = 9.80$; $p < 0.05$), while no sighting was reported for the fourth time slot.

The mean latency among sightings in the Mykali area was 57 days. The shortest was two days, the longest was 231 days. Sightings came in bouts and latency changed with the seasons: during the spring the mean latency was 15 days, during the summer it was 24 days.

For all sightings detected in Mykali Bay, the monk seal was observed in shallow waters within 100 m from the shore (Figure 2c), allowing the collection of behavioural data. Monk seal individuals were typically observed while transit feeding (43%). Swimming with head above water in coastal waters (27%) and spot feeding (24%) were also recorded. Scanning the environment represented the remaining 6% of the total recorded behaviours.

The photo-identification did not support any specific identification of individuals nor the determination of sex, but only identification of the age class.

3.2. Opportunistic Sightings

Sightings of 19 individuals were recorded along the coastline of Samos Island (Table 4; Figure 1). Of the total 19 sighted individuals, five were identified as pups.

All four sighted pups recorded in September 2017 were confirmed to be the same individual by the researchers monitoring the coastline following the first report and after analysing the pictures reported by the citizens. The distinctive colour patch of the umbilical area together with the size of this pup suggested that the individual was a recently born female (Figure 2b) [25]. In September 2018, one pup was spotted in the proximity of a cave known as the “monk seal cave” where the local citizens have reported the historical presence of monk seals. Except for the female pup in 2017, sex was undetermined and the age class was estimated from the size of the individuals.

On only two occasions were two individuals spotted together. On the first occasion two individuals were observed together in the north-western side of the island, close to the coastal cliff, exhibiting the behaviour of swimming together at the surface (Table 4 record N° 14). On the second occasion, two individuals were observed porpoising synchronously (Table 4 record N° 18) in the south-eastern side of the island, approximately 200 m from the shore in the proximity of the Mykali area.

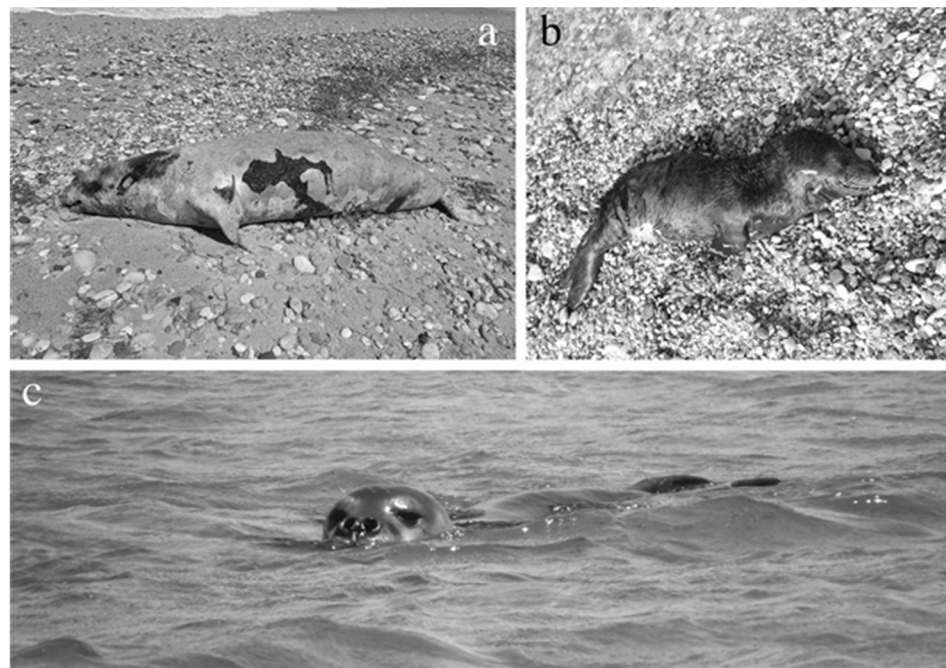


Figure 2. (a) Carcass of an adult male monk seal found on 17 April 2019 at Potami Karlovasi (Table 5 record N° 4); (b) Female monk seal pup found on 8 September 2017 at Kokkari beach (Table 4 record N° 5); (c) Adult/subadult monk seal swimming in Potami Mesokampou on 19th April 2018 (Table 4 record N° 8)—Samos Island, Greece (photo credits: Dr Guido Pietroluongo/Magali Raynaud).

Table 4. Opportunistic sighting records in Samos Island between 2017 and 2019.

No	Date	Location	Number of Individuals	Age Class	Observer Type
1	7 May 2017	Mykali Bay	1	Adult/Subadult	Researcher
2	1 July 2017	Potami Mesokampou	1	Adult/Subadult	Researcher
3	3 September 2017	Megalo Seitani	1	Pup	Researcher
4	7 September 2017	Agio Kostantinos	1	Pup	Researcher
5	8 September 2017	Kokkari	1	Pup	Researcher
6	9 September 2017	Tsamadou	1	Pup	Researcher
7	23 October 2017	Kato Kiriako	1	Adult/Subadult	Researcher
8	19 April 2018	Potami Mesokampou	1	Adult/Subadult	Researcher
9	24 April 2018	Vathy Port	1	Adult/Subadult	Port authority
10	19 May 2018	“Monk Seal Cave”, Kerveli	1	Adult/Subadult	Diver
11	12 August 2018	Pythagorio Port	1	Adult/Subadult	Fisherman
12	14 September 2018	“Monk Seal Cave”, Kerveli Bay	1	Pup	Diver
13	20 October 2018	Karlovassi Port	1	Adult/Subadult	Port authority
14	11 November 2018	Mikro Seitani	2	Adult/Subadult	Researcher
15	16 January 2019	Samos Marina	1	Adult/Subadult	Port authority
16	2 August 2019	Pythagorio Port	1	Adult/Subadult	Researcher
17	15 October 2019	Pythagorio Port	1	Adult/Subadult	Fisherman
18	21 October 2019	Potami Mesokampou	2	Adult/Subadult	Researcher
19	15 November 2019	Pythagorio Port	1	Adult/Subadult	Fisherman

Table 5. Stranding records in Samos between 2017 and 2019.

No	Date	Location	Latitude N (°)	Longitude E (°)	At Stranding, Condition Code of Carcass	Sex	Age Class	Evidence of Negative Anthropogenic Interaction
1	20/05/2017	Kampos Marathokampou	37.70982	26.69186	fresh carcass	Female	Subadult	Yes
2	23/10/2017	Tsopela	37.64011	26.83258	moderate decomposition	Male	Adult	ND
3	14/03/2019	Glyfos Kerveli	37.72729	27.03958	moderate decomposition	Female	Adult	No
4	17/04/2019	Potami Karlovasi	37.78942	26.66318	moderate decomposition	Male	Adult	Yes

3.3. Opportunistic Stranding's Records

A total of two strandings occurred in 2017 (one in spring and one in autumn), two in 2019, one month apart (one in winter and one in spring), and none in 2018 (Table 5).

Based on the morphometric measurements and the pelage pattern [23], two adult males, one adult female, and one subadult female were identified. Physical evidence associated with human interaction was recorded in two of the four carcasses examined. The presence of bullets was recorded in the ventral region of the body for the subadult female in 2017, and in the head region for the adult male found dead in 2019 (Table 5 record N° 4; Figure 2a). The subadult dead female in 2017 (Table 5, record N° 1) was identified as the well-known individual named “Argiro” by the local community. Argiro was spotted for the first time on the island in 2014 as a weaned animal. Its sightings were very frequent year-round, and all around the island of Samos, especially in proximity of synanthropic areas (ports, touristic beaches), where it was often vulnerable to human interaction.

4. Discussion

A combined methodological multi-approach was applied to investigate the presence of monk seals in the coastal waters of Samos. Dedicated visual monitoring surveys, integrated with opportunistic, citizen science, and stranding data, enabled assessment of the species occurrence and its seasonality. The results indicated that monk seals are regularly present in the coastal areas of Samos Island, confirming the importance of this zone for the species [26,27] and helping to fill the knowledge gap for recent years.

When monitoring and opportunistic data were pooled together, monk seals appeared to be constantly present in Samos' coastal waters though the sighting frequency recorded from Mykali beach varied among year, season, and time of the day. When the presence was not reported in the Mykali area, the sightings were opportunistically reported elsewhere. In 2019, no presence was recorded in the Mykali area after the winter, but sightings were reported in the nearby area of the Pythagorio port during the summer and fall.

The seasonal occurrence of sightings collected during systematic surveys at Mykali beach seems to be complementary to those opportunistically collected around the island. Therefore, the statistical difference may be related to different seasonal use of Samos' coastal waters, which may be associated with the monk seals' behaviour and ecology or might be the result of human disturbance. Further investigation is necessary concerning the on-site fidelity of individuals, habitat use and behavioural ecology to shed light on this question.

Considering that 59% of sightings were located at sites other than Mykali, and that monk seals were likely to utilise the various marine habitats around Samos Island, it is clear that conservation measures should target specific marine and coastal areas surrounding

the entire island. Furthermore, the number of sightings reported in Mykali Bay (41% of the total sightings of the island), and the behaviours recorded (mainly transit feeding), are consistent with the hypothesis that the Mycale Strait represents a natural corridor for monk seals. Previous studies [5,28,29] have already identified the island of Samos as one of the four priority areas for the monk seal within the eastern Mediterranean metapopulation. This is further reinforced by the presence of the Dilek Peninsula-Büyük Menderes Delta National Park on the Turkish shore located nearby, where lower human disturbance and tourism, together with the assessment of the availability of suitable feeding and breeding habitats, may offer a sheltered refuge for monk seal breeding nuclei and recolonisation. So, ecological corridors within the home range of the metapopulation could have strategic significance for the different habitat use between the Turkish and Greek coasts [30,31].

The presence of pups confirms that the island continues to be an important breeding area, as previously suggested by Adamantopoulou et al. [32], and supported by the presence of the weaned seal named Argiro. The two pups recorded during the pupping season were observed in locations characterized by cliffs and caves, validating their reported preference for sheltered areas [1,2]. The geographical distribution of pup sightings may support "Seitani" as an important site for the conservation of the species. Indeed, this area was already designated as a site of priority for the species in 1980 [17] and, a few years later, a Presidential Decree (100/27-2-1995) placed the northwestern region of the Samos coast under strict protection for monk seal conservation. Nevertheless, this study has also highlighted the presence of pups on the north-eastern side of the island, indicating that further studies and protection measures for breeding sites could be extended.

The presence of two individuals at the same time was reported for only two sightings during spring in different years. The age class of the individuals and the behaviour recorded of these sightings may suggest mating or a male's territorial displays, highlighting the importance of protecting habitats used at different stages of the pinniped's life.

The stranding data may suggest that Samos' waters are visited by different individuals. Two monk seal carcasses, representing 50% of the total number, provided evidence of negative anthropic interactions, and serve as an indicator of persistent human conflicts and persecution, previously documented in Greece and this part of the Aegean Sea [26,27]. In particular, the lone, sociable Argiro represents an example of long-time conflicts with humans, tourism, and fishery on a Greek island. Stranding data represent significant indicators of marine mammal population in a specific area [33] and, therefore, these records must be taken into consideration in the management process. However, it was not possible to determine the mechanism and cause of death, highlighting the need to develop more extensive post mortem investigations in this area to assess the impact of anthropic interactions and natural factors on the monk seals living in Samos' waters.

Opportunistic citizen reports have been found to be the most efficient tool for monitoring the presence of this cryptic species, enabling identification of regions with high frequencies of sightings, where to expand further dedicated monitoring activities and protection actions, and helping to reinforce public awareness for conservation purposes.

The combination of different monitoring approaches enabled investigation of the recent occurrence and threats to monk seals in the Samos coastal zone over a wider spatial and temporal range. Habitat use and suitability, and behaviour and anthropogenic pressure across the island and the surrounding archipelago need to be further assessed in the long term to better understand the extent of the monk seal population and to adapt management measures accordingly. In parallel, targeted awareness and educational campaigns could improve the engagement of local communities and visitors in the conservation of the monk seal, as well as in the preservation and recovery of its habitat [34,35].

In the future, considering the presence of numerous caves on the island, further and more detailed investigations on pupping and systematic monitoring of breeding of the species in the island are required to provide more concrete conclusions on the presence of the seals in this area. Well-defined areas should be systematically monitored to better understand the seasonal movement patterns of the monk seals in Samos' waters, and, potentially, to identify single individuals.

5. Conclusions

The results of the study show that using a combination of monitoring approaches can contribute to filling the knowledge gap regarding the Mediterranean monk seal, adopting effective methods which may be selected by a variety of researchers in different locations. This recent data contribution is pivotal for extending knowledge of the overall Aegean population, and provides new insights into the species' survival and threats in this region. This study has also confirmed that, after 20 years, the northwestern side of Samos Island still represents an area of significant importance for the Mediterranean monk seal. Moreover, the presence of monk seals in new areas, such as the eastern side of the island and the Mycale Strait, together with the presence of pups, represents crucial information for the conservation of this species. This is even more important in light of the biodiversity descriptor within the EU Marine Strategy Directive Framework, as well as the EU Biodiversity Strategy for 2030. In particular, the overlap zones between non-EU (Turkey) and EU (Greece) members highlight the necessity for international collaborative studies.

Sighting data, together with stranding data, show that the Mediterranean monk seal continues to face the same threats in most recent years. Facilitating data input within the IMMA context will be crucial for the implementation of effective protection measures, focused on breeding nuclei, human interaction, and habitat degradation, so that seal presence in such sites may increase and seals will be able to disperse to and recolonise these areas. Continuing to promote new research approaches, capacity building, awareness campaigns and the protection of suitable habitats is essential for the conservation of the Mediterranean monk seal in Greek waters.

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