

## Short Note

### First Observations of Aquatic Sleep in the Mediterranean Monk Seal (*Monachus monachus*)

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The Mediterranean monk seal (*Monachus monachus*) is the only resident pinniped in the Mediterranean Sea. With fewer than 700 individuals worldwide (Karamanlidis et al., 2016), the species is listed as “Endangered” by the International Union for the Conservation of Nature (IUCN) (Karamanlidis & Dendrinos, 2015) and is one of the most endangered marine mammals on Earth. The largest Mediterranean monk seal subpopulation occurs mainly on the islands of the Aegean and Ionian Seas and along the coasts of mainland Greece. Despite encouraging signs of partial subpopulation recovery, the species is still threatened by habitat destruction, deliberate killing, and accidental entanglement in fishing gear (Karamanlidis et al., 2016). Improvement in our understanding of its behaviour is necessary to design and implement effective conservation measures that will safeguard the future of the Mediterranean monk seal in Greece (Notarbartolo di Sciara et al., 2009).

The sleep physiology of pinnipeds has been thoroughly studied in managed care (e.g., grey seal [*Halichoerus grypus*], Ridgway et al., 1975; harp seal [*Pagophilus groenlandicus*], Lyamin, 1993; northern elephant seal [*Mirounga angustirostris*], Castellini et al., 1994; northern fur seal [*Callorhinus ursinus*], Lyamin & Mukhametov, 1998). As in all terrestrial mammals (e.g., Siegel, 2011), sleep in pinnipeds consists of two stages: (1) Slow Wave Sleep (SWS) and (2) Rapid Eye Movement (REM) sleep (Lyamin et al., 2013). The sleeping patterns and behavior of the Otariidae and Phocidae differ considerably, however. Captive Otariids usually sleep at the surface on their sides while breathing regularly. Fur seals sleep in a characteristic position, holding their nostrils, two hind flippers, and one front flipper above the surface; to maintain this position, they paddle with the other fore flipper

(Lyamin & Mukhametov, 1998). This characteristic position also has been observed in fur seals sleeping in open waters (Donohue et al., 2000). Otariids display bilateral SWS and REM sleep (Lyamin & Chetyrbok, 1992; Lyamin & Mukhametov, 1998; Lyamin et al., 2002, 2013) as observed in terrestrial mammals, and unihemispheric SWS as observed in cetaceans (Lyamin et al., 2008). It has been suggested that unihemispheric sleep allows cetaceans to briefly open one eye to monitor the environment, to move in the water to control position and optimize thermoregulation, and to facilitate breathing to minimize respiratory aspiration (Lyamin & Mukhametov, 1998; Lyamin et al., 2013). True seals (e.g., grey seal, Caspian seal [*Pusa caspica*], and harp seal) can hold their breath while sleeping; this allows them to sleep while floating motionless at the surface or at depth (in horizontal or vertical positions, a behavior known also as “bottling”), or while lying on a pool bottom (Ridgway et al., 1975; Lyamin, 1993; Castellini et al., 1994). Research has shown that SWS in true seals occurs in both brain hemispheres simultaneously as in all terrestrial mammals (Mukhametov et al., 1984; Lyamin, 1993; Castellini et al., 1994). REM sleep episodes in water have been recorded during single apneas while the seals were submerged under water or resting on pool bottoms (Lyamin, 1993; Castellini et al., 1994). Bihemispheric SWS and REM sleep are incompatible with any substantial movement; therefore, when true seals sleep at depth, they have to wake up to initiate movement to the surface to breathe. In contrast, they do not always need to wake from SWS to breathe when sleeping at the surface (Lyamin, 1993; Castellini et al., 1994).

Research on the behaviour of the Mediterranean monk seal in Greece has focused mainly on monk seals on land when using marine caves for resting and pupping (e.g., Dendrinos et al., 2007b;



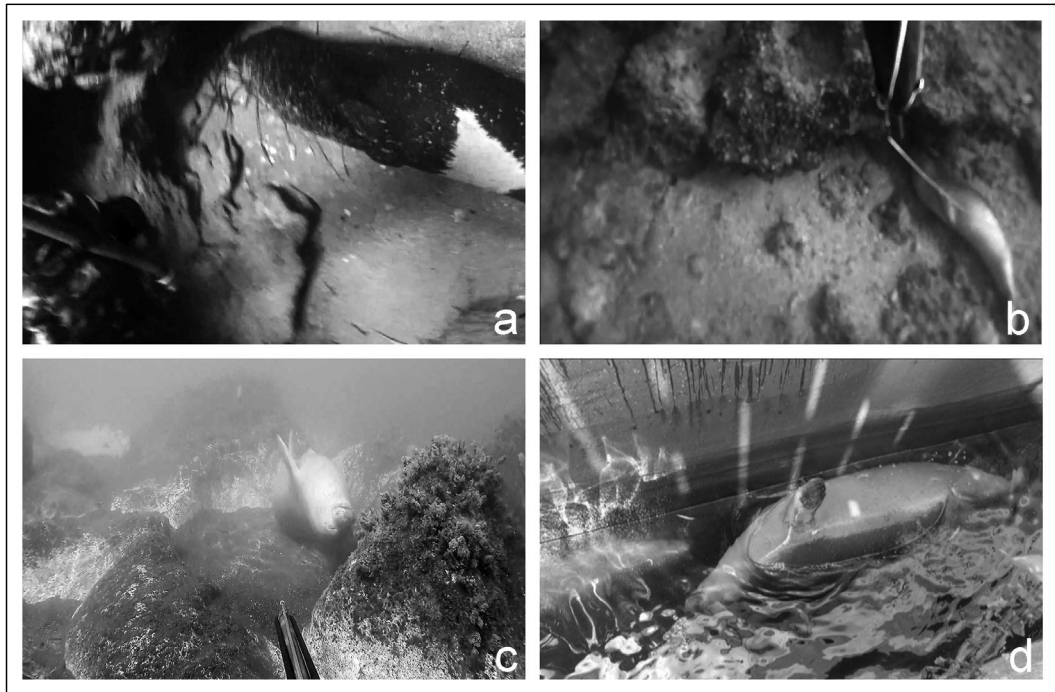
**Figure 1.** Map of Greece indicating the locations where Mediterranean monk seals (*Monachus monachus*) were observed sleeping; numbers 1 through 6 indicate the locations for each observation included in this paper.

Dendrinos, 2011). Relatively little is known about the behaviour of the species at sea. Herein, six observations of monk seals sleeping at sea are reported, and the importance of understanding their behaviour to shape the conservation strategy for the Mediterranean monk seal in Greece is evaluated. All observations were made between 2011 and 2016, either directly by our research group or by speargun fishermen who provided video footage, which we then analyzed (video footage is available on the *Aquatic Mammals* website: [www.aquaticmammals-journal.org/index.php?option=com\\_content&view=article&id=10&Itemid=147](http://www.aquaticmammals-journal.org/index.php?option=com_content&view=article&id=10&Itemid=147)). In the observations where video footage was provided by speargun fishermen, follow-up interviews were conducted to collect additional information regarding the circumstances surrounding each observation.

**Observation 1** – The first observation was made by a speargun fisherman on 27 March 2011 at

approximately 0900 h at Diaporti, Sithonia, in northern Greece (40.015029 N, 23.818750 E; Figure 1). An adult male monk seal was encountered lying on its belly at the sea bottom with its eyes closed at ~5 m depth. When approached to a distance of ~10 m, the seal woke up and swam away.

**Observation 2** – At 1330 h on 21 September 2012 at Veneto, Pilio, in northern Greece (39.550072 N, 22.987565 E; Figure 1), another speargun fisherman observed a different adult male sleeping on the sea bottom. The monk seal was lying on its right side at ~4 m depth with both eyes and nostrils closed (Figure 2a). The speargun fisherman was almost able to approach close enough to touch the seal (approximate distance: < 1 m) without it waking. The speargun fisherman left the animal alone believing that it was dead, but when he returned moments later with his diving companion, the animal was gone and not encountered again.



**Figure 2.** (a) Image of the adult male Mediterranean monk seal encountered in Observation 2 (Photo by K. Koulakoglou); (b) image of the juvenile Mediterranean monk seal encountered in Observation 3 (Photo by N. Gougoulas); (c) image of the juvenile male Mediterranean monk seal encountered in Observation 5 (Photo by P. Danezis); and (d) image of the adult female Mediterranean monk seal encountered in Observation 6 (Photo by P. Dendrinis).

*Observation 3* – A different speargun fisherman made the third observation on 1 September 2014 at 1815 h at Loutropoli Thermis, Lesvos Island, in the Aegean Sea (39.195000 N, 26.504167 E; Figure 1). A juvenile monk seal was encountered sleeping at the sea bottom (Figure 2b); the seal was lying on its right side at ~7 m depth. The speargun fisherman was able to approach within 2 m of the seal before it woke up and fled.

*Observation 4* – The fourth observation of a sleeping monk seal by a speargun fisherman was on 13 June 2015 at 0745 h at Marmaritsa, Maronia, in northern Greece (40.868218 N, 25.527202 E; Figure 1). An adult male was observed sleeping at the sea surface with its dorsal side up. The seal was floating horizontally and drifting in the waves with its head below water and its eyes and nostrils closed. The speargun fisherman was less than 3 m from the seal before it woke up and moved slowly away.

*Observation 5* – Another speargun fisherman saw the fifth instance of a sleeping monk seal on 25 March 2016 at 1330 h at the island of Sandorini in the Aegean Sea (36.413867 N,

25.485300 E; Figure 1). A juvenile male was encountered sleeping at the sea bottom at ~5 m depth, with its eyes and nostrils closed. The seal was initially observed lying on its ventral side; but in the strong current, its sleeping position changed with the seal shifting to its right side and then its back (Figure 2c). When approached within less than 2 m, the seal woke up and fled.

*Observation 6* – Our research group observed the sixth monk seal on 15 May 2016 at 1130 h at the harbor of Piraeus (37.942290 N, 23.630901 E; Figure 1). Because of the unusual location, our research group was initially contacted because it was thought that the animal might be in distress. However, the adult female was found sleeping horizontally on its left side at the sea surface between the harbor docks and an anchored cargo ship with its head below water and eyes and nostrils closed (Figure 2d). One measured apnea lasted for ~3 min. After this apnea, the seal turned on its ventral side and resumed breathing with an interval of 5 to 8 s without opening its eyes, which would indicate waking up.

Although sleeping seals have been frequently witnessed in the wild (e.g., Hawaiian monk seal

[*Neomonachus schauinslandi*], C. Littnan, pers. comm., 1 July 2016; grey seals, Thompson et al., 1991; bearded seal [*Erignathus barbatus*], C. Kovacs, pers. comm., 2 July 2016), occurrences of aquatic seal sleeping in the wild, to our knowledge, have not been published previously. However, it has been indirectly inferred in northern elephant seals and Hawaiian monk seals instrumented with data loggers and CRITTERCAMS, respectively (Parrish et al., 2000; Mitani et al., 2010).

Herein, we provide the first evidence of Mediterranean monk seals sleeping at sea. The aquatic sleeping behavior of the Mediterranean monk seal is undoubtedly similar to that observed in other captive and free-ranging true seals (Ridgway et al., 1975; Lyamin, 1993; Castellini et al., 1994; Mitani et al., 2010), including the ability to sleep while breath-holding, both at the sea surface and at the bottom. Sleeping at the sea bottom minimizes the time spent at the surface and serves in some seal species as a way to avoid predation by killer whales (*Orcinus orca*) and sharks (Lyamin et al., 2013). Photographic evidence received by our research team indicates that Mediterranean monk seals can also sleep at the surface in a “bottle” position. As in other Phocidae (e.g., Mukhametov et al., 1984; Lyamin, 1993; Castellini et al., 1994), SWS in the Mediterranean monk seal is likely bihemispherical as the seals were motionless with both eyes closed in all videos analyzed; monk seals did not wake up and swim away before being approached at a close distance. We did not record any evidence of REM sleep in Mediterranean monk seals such as muscle jerks and body twitches that are typical for REM sleep in other phocids (Mukhametov et al., 1984; Castellini et al., 1994; Lyamin et al., 2013). However, this could be because of our small sample size and the short duration of the videos analyzed.

Since the beginning of systematic monitoring efforts for the Mediterranean monk seal in the 1970s (Sergeant et al., 1979), researchers have been puzzled by the terrestrial activity patterns of Mediterranean monk seals in Greece. Cave habitat use by these seals appears highly seasonal, with individuals of both sexes and all age classes using marine caves mainly during the breeding season from late summer to late winter but comparatively rarely thereafter (Dendrinos et al., 1994, 2007b; Dendrinos, 2011). This has raised the question of the whereabouts of Mediterranean monk seals during the rest of the year. Trying to answer this question and study the behavior of Mediterranean monk seals at sea in Greece has been hampered by the difficulty of tagging animals in the wild because of their endangered status, the inaccessibility of their habitat, and the difficulties encountered with satellite telemetry, particularly when haul-out sites are located near steep cliffs (Jay & Garner, 2002;

Dendrinos et al., 2007a). Considering that individual behavior defines spatial structure and resource use on a population level (Turchin, 1998), the difficulties encountered in studying the Mediterranean monk seal have led to a significant gap in our understanding of this species' behavior (Bergman et al., 2000). It appears, however, that the current observations provide a possible explanation for the reduced use of marine caves by monk seals in Greece during the nonbreeding season. They simply do not use the marine caves. Our observations indicate that Mediterranean monk seals seem secure enough to sleep either at the sea surface or below on the sea floor and, thus, do not necessarily need land to meet sleep requirements. We believe that some individuals might lead a predominantly aquatic life during the nonbreeding season.

The aquatic sleeping behavior of Mediterranean monk seals has important implications for the conservation of the species in Greece. Lack of information on the behavior of Mediterranean monk seals at sea has forced conservation efforts to be focused primarily on protecting the species on land, where the identification of all suitable breeding caves and the establishment of a network of protected sites are considered a conservation priority. The fact that Mediterranean monk seals can, according to these observations, sleep at sea, highlights the necessity to prioritize nationwide conservation actions in the marine environment. These actions should go hand-in-hand with those to mitigate negative seal-fishery interactions in Greece as identified in the National Strategy and Action Plan (Notarbartolo di Sciara et al., 2009), and with efforts to increase public awareness with the main target groups: people with the potential to have frequent contact with monk seals such as artisanal fishermen, spear-gun fishermen, and scuba divers.

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