# Mediterranean Monk Seal *Monachus monachus* (Hermann, 1779)

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## Contents



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## Common Names

| | |
|---|---|
| English | Mediterranean monk seal |
| German | Mittelmeer-Mönchsrobbe |
| French | Phoque moine |
| Spanish | Foca monje |
| Italian | Foca monaca |
| Russian | белобрюхий тюлень |

## Taxonomy, Systematics and Paleontology

The Mediterranean monk seal *Monachus monachus* (Hermann, 1779) (Fig. 1), the Hawaiian monk seal *Neomonachus schauinslandi,* and the now extinct Caribbean monk seal *Neomonachus tropicalis* used to be grouped together in the genus *Monachus*, a group of seals inhabiting sub-tropical and temperate waters. However, latest findings on the genetics and morphology of the species have led to a separation of this taxonomic group, leaving the Mediterranean monk seal as the sole representative of the genus *Monachus* (Scheel et al. 2014). The Mediterranean monk seal was described for the first time by Aristotle (Johnson and Lavigne 1999), while the first scientific description of the species was authored in 1779 by Johann Hermann, who named the species *Phoca monachus* due to its visual resemblance to a hooded monk (Johnson 2004) and not because, as sometimes speculated (Scoullos et al. 1994), of its solitary habits.

Little is known about the historical past of the Mediterranean monk seal. The fossils unearthed to date (Tavani 1943; Boettger 1951; Ray 1976; Springhorn 1978; Barnes et al. 1985) indicate that monk seals are, in evolutionary terms, a remarkably conservative group.

## Phylogeny and Phylogeography

Phylogenetics and phylogeography of the Mediterranean monk seal are still not fully understood. Phylogenetic analyses of the mitochondrial DNA of the Mediterranean and the Hawaiian monk seal indicate a deep divergence between the two species and a mid-late Miocene origin of the lineage (Davis et al. 2004). The date of this divergence was dated back to 10.6-11.6 million years ago by Fyler et al. (2005), to 11.3 MYA ago by Higdon et al. (2007), and to ~13 MYA by Arnason et al. (2006).

There is also uncertainty about the phylogeographic origin of the species and how monk seals came to inhabit seas as far apart as the Mediterranean, Caribbean Sea and Pacific Ocean. Reppening et al. (1979) proposed that *Monachus* started its evolutionary journey at the eastern seaboard of Northern America and reached Europe with the help of the warm Gulf Stream. This hypothesis has been supported recently by Arnason et al. (2006), who examined the mitochondrial genome of the Hawaiian monk seal and select genes of the Mediterranean monk seal. A second, alternative hypothesis of the phylogeographic origin of the Mediterranean monk seal has been originally suggested by Hendey (1972) and de Muizon (1982) and more recently by Fyler et al. (2005) and Higdon et al. (2007).

**Fig. 1** An adult female Mediterranean monk seal and her newborn pup. © Alexandros A. Karamanlidis/MOm

According to this hypothesis the original ancestor of the monk seals began its journey in the Tethys, giving birth to the Mediterranean monk seal. Following the warm equatorial currents, some animals managed to cross the Atlantic and traveled north the Caribbean, giving rise to the Caribbean monk seal. Eventually, after crossing the Pacific, they reached the Hawaiian Islands and evolved into the Hawaiian monk seal. Recent examination, however, of fossil evidence from the Pliocene of New Zealand suggests another alternative, where monachine seals in fact evolved in the southern Hemisphere, before moving northwards and settling in the latitudes they are currently found (Rule et al. 2020).

## Current Distribution

The Mediterranean monk seal is the only resident seal species in the Mediterranean Sea. The species was once widely distributed throughout the Black and Mediterranean Seas, and in North Atlantic waters from Cabo Blanco in the south to Morocco and northern Spain in the north, including the Azores, Madeira and the Canary Islands (González 2015; Karamanlidis et al. 2016a). Vagrants have been recorded in the past in Senegal, the Gambia, the Cape Verde Islands, and Atlantic France, but the origin of these individuals is unknown (Karamanlidis et al. 2016a).

Mediterranean monk seals have a long history of exploitation by humans, starting in prehistoric times (Johnson and Lavigne 1999; Johnson 2004; Stringer et al. 2008) and continuing throughout the Roman era (Johnson and Lavigne 1999) and in certain areas, such as Madeira and the Canary Islands and the Bay of Dhakla in Western Sahara, the Middle Ages (Isräels 1992; Johnson 2004; Brito 2012; González 2015). Negative interactions with humans during most of the twentieth century have led to the extinction of the Mediterranean monk seal from most of its former range. The Mediterranean monk seal has recently been extirpated from mainland France and Corsica, Spain and its Balearic Islands, mainland Italy and Sicily, Egypt, Israel, Lebanon and the Black Sea. Due to a lack of repeated sightings of different individuals, the Mediterranean monk seal should be considered effectively extinct also in Sardinia, Tunisia, and Algeria (Karamanlidis and Dendrinos 2015; Karamanlidis et al. 2016a; Karamanlidis et al. 2019).

As a result of this population decline, the distribution of the Mediterranean monk seal (Fig. 2) has now been virtually reduced to three sub-populations, one in the north-eastern Mediterranean Sea and the other two in the north-eastern Atlantic, off the coast of north-west Africa (i.e., at the Cabo Blanco coast in Mauritania/Morocco and in the Archipelago of Madeira) (Karamanlidis et al. 2003; Pires et al. 2008; Pires 2011; González and Fernandez de Larrinoa 2012; Martínez-Jauregui et al. 2012; Pires et al. 2020; Fernandez de Larrinoa et al. 2021). Genetic evidence (Karamanlidis et al. 2016b; Gaubert et al. 2019) and the large distance between them make it unlikely that there is currently any genetic exchange between these three sub-populations. The Mediterranean monk seal population in the north-eastern Mediterranean Sea and the Madeiran population are the only sub-populations in Europe.

With an estimated total population of currently less than 1000 individuals, the Mediterranean monk seal is considered to be the most endangered seal species and one of the most endangered marine mammals in the world. More than half of the total population of the Mediterranean monk seal lives in the north-eastern Mediterranean Sea. The Area of Occupancy (AOO) of this sub-population covers more than 90% of the

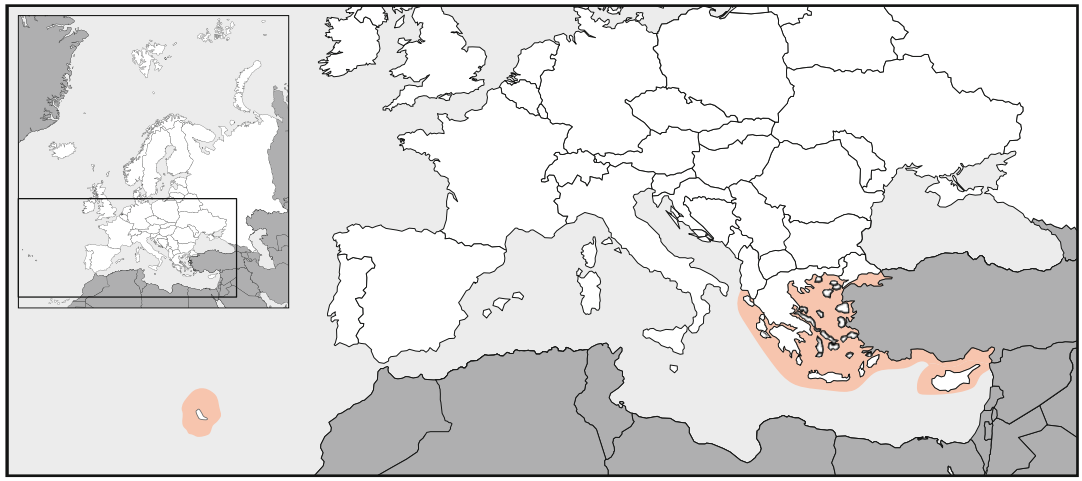


**Fig. 2** Distribution range of *Monachus* Hermann, 1779 in the Mediterranean Sea. The distribution map is based on the IUCN Red List of Threatened Species. Version 2019-3. (Map template: © Getty Images/iStockphoto)

worldwide AOO of the species (Karamanlidis and Dendrinos 2015; Karamanlidis et al. 2016a, 2019) and is the main focus of the species presentation in this chapter. In the Atlantic, approximately 350 individuals live in the Cabo Blanco colony (Fernandez de Larrinoa et al. 2021) and <30 individuals live in the Archipelago of Madeira (Pires et al. 2020).

In the north-eastern Mediterranean Sea, the species is mainly found around islands in the Ionian and Aegean Seas in Greece (Adamantopoulou et al. 2022) and along the mainland coasts of Greece and western and southern Türkiye (Güçlüsoy et al. 2004; Gücü et al. 2004, 2009a, b; Kıraç et al. 2013). Some individuals survive also in the Sea of Marmara (Inanmaz et al. 2014). An unknown number of monk seals might still survive along the Mediterranean coasts of eastern Morocco (Mo et al. 2011), but without systematic monitoring the status and fate of this subpopulation remains uncertain (Karamanlidis et al. 2016a).

In recent years, sporadic, extralimital occurrences of individual monk seals have been reported in countries where the species has long considered to be effectively extinct, such as Albania, Croatia, Egypt, Israel, Italy, Lebanon, Libya, Spain, and Syria (Karamanlidis et al. 2016a; Bundone et al. 2019). Following an increase in the number of sightings and the annual recording of reproductive events in the last decade, the Mediterranean monk seal is considered to have re-established itself recently on the island of Cyprus (Nicolaou et al. 2019).

## Description

### Size and Morphology

Mediterranean monk seals are medium-sized phocids (Fig. 3) (Gilmartin and Forcada 2002). Morphological studies from Cabo Blanco indicate that male Mediterranean monk seals are only slightly larger than females (Samaranch and González 2000), with the average Total Body Length (TBL) of adult females and males measured at 2.42 and 2.51 m, respectively. Studies from Greece indicate no significant difference between sexes in mean Standard Body Length (SBL; male = 218.3 cm; female = 215.9 cm) (Murphy et al. 2012). Mean SBL for both sexes in Cabo Blanco and maximum body size (270 cm for males) appears to be slightly larger than that of the north-eastern Mediterranean sub-population. Average length at birth is approximately 100 cm (range: 88–103 cm) (Samaranch and González 2000; Dendrinos 2011). Newborn pups weigh


**Fig. 3** The characteristic morphology of the Mediterranean monk seal: (**a**) a newborn pup with its characteristic lanugo fur and the white patch on the ventral side of its body; (**b**) a juvenile monk seal with a slim, elongated body and few external morphological characteristics (scars); (**c**) an adult female with a characteristic light brown or grayish pelage and numerous scars on the dorsal side of the body; (**d**) an adult male, showing the characteristic white patch on the ventral side of its body and numerous scars at the throat and hind flippers. Photographs: (**a**, **b**) © Panagiotis Dendrinos/MOm, (**c**, **d**) © Alexandros A. Karamanlidis/MOm

15–26 kg (Marchessaux and Pergent-Martini 1991; Dendrinos 2011), and adults are believed to weigh 240–300 kg; the maximum weights reported for the species are 400 kg for an adult male and 302 kg for a pregnant female (Sergeant et al. 1978; Boulva 1979; Marchessaux and Pergent-Martini 1991).

## Pelage

Monk seal pups are born with a characteristic black to dark chocolate coat (also known as "lanugo" fur) and a white patch on the ventral side of their body (Badosa et al. 1998; Dendrinos 2011). The hair of the neonatal pelage is soft and woolly and approximately 1.0–2.0 cm in length (Boulva 1979). The shape, size, and position of the ventral patch, which is often spotted (Dendrinos 2011), vary between individuals and according to gender (Badosa et al. 1998). The white patch on the ventral side of the pups is distinctive of the species and is/was not present in the Hawaiian and Caribbean monk seal.

Mediterranean monk seals are sexually dimorphic in their external appearance, with characteristic morphological differences between different maturity stages/age classes (Samaranch and González 2000). In contrast to adult females that are generally brown or gray with a lighter belly, adult males have an overall black pelage with a white belly patch (Samaranch and González 2000; Dendrinos 2011). Intense social and mating interactions often result in scarring on the throats and hind flippers of males and on the backs of females (Forcada and Aguilar 2000; Samaranch and González 2000). Juvenile and adult Mediterranean monk seals have very short and bristly hair of about 0.5 cm long, the shortest hair among pinnipeds (Ling 1970), which lie close to the animal's body, thus forming a close-cropped pelt.

## Dentition

The dentition of the Mediterranean monk seal (Fig. 4) contains two incisors, one canine, and five molars on each upper and lower jaw (Ranzani 1823; Carruccio 1893; King 1956) and differs from that of the Hawaiian monk seal (Ronald 1973). The incisors of the Mediterranean monk seal are characterized by their big size and a small ridge located at the back side of the tooth (Duguy and Marchessaux 1992). Compared to the Hawaiian monk seal, dental development at Mediterranean monk seals is delayed, starting at the age of 2–3 weeks, does not follow a well-defined teeth eruption pattern, and does not appear to be associated with the health or nutritional status of the newborn pup (Androukaki et al. 2002).

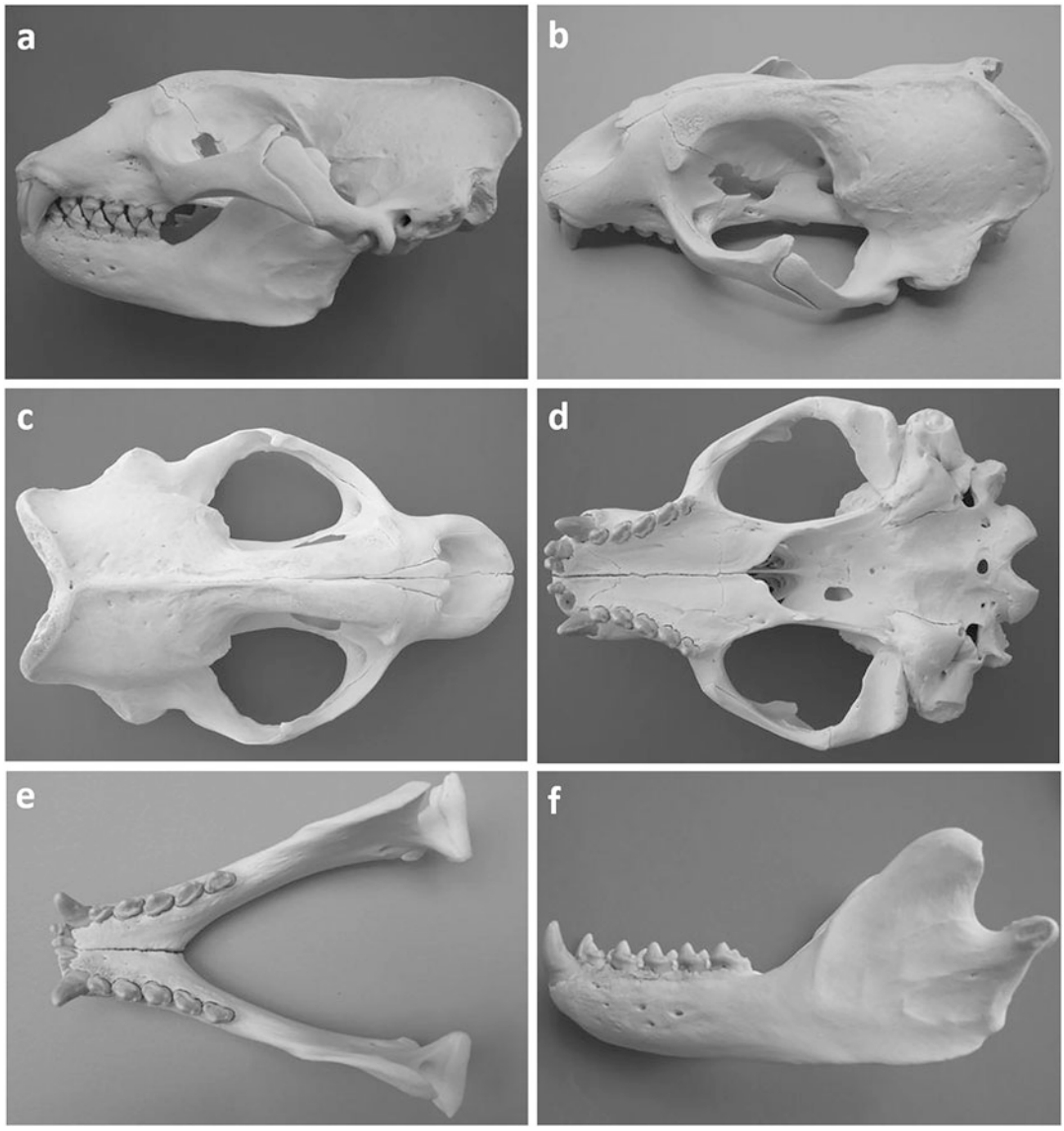


**Fig. 4** View of the Mediterranean monk seal's cranium and mandible. (**a**, **b**) lateral, (**c**) dorsal, (**d**) ventral view of skull, (**e**) dorsal view of mandible, (**f**) lateral view of left mandible (view from outside). With kind permission from Ahmet Çakır, İsmail Gökçe Yıldırım, and Okan Ekim

### Age Determination

Age determination in the field is usually based on the external, morphological differences and the differences in size of the distinct age classes. Pups (1–2 months) are characterized by their lanugo fur and the distinctive white patch of fur on the ventral side (Fig. 3). Following first molt, weaners (3–6 months; 141–152 cm) (Murphy et al. 2012) attain the characteristic grayish pelt of the Mediterranean monk seal. From this stage on and until sexual maturity it is very difficult to distinguish the sex of subadult Mediterranean monk seals (7 months to 3–6 years; 149–195 cm) from their external appearance and without observing the penile opening. Upon attaining sexual maturity, approximately at the age of four (196–250 cm) (Koemtzopoulos et al. 2022), male Mediterranean monk seals are distinguished by their black coat, the white patch on their ventral side (this patch is different in shape and size in every animal), and the numerous scars on the throat and hind flippers (Fig. 3). Adult female Mediterranean monk seals have a uniformly grayish/brown coat that is always lighter ventrally. They are also distinguished by the numerous "mating" scars on their dorsal side, which increase over time (Fig. 3).

## Physiology

No published information is available.

## Genetics

### Chromosomes

No published information is available.

### Genetic Diversity

The Mediterranean monk seal is characterized by extremely low variability at all genetic markers examined to date, including microsatellite loci, the mitochondrial control region (Schultz 2011), and the MHC class I genes (Gaughran 2013). Genetic analyses of mitochondrial and nuclear DNA have shown that, as a consequence of severe population bottlenecks and population fragmentation, all sub-populations of the species exhibit low levels of genetic diversity (Pastor et al. 2004; Pastor et al. 2007; Karamanlidis et al. 2016b; Gaubert et al. 2019). In fact, the mitochondrial DNA diversity of Mediterranean monk seals is among the lowest recorded in any pinniped species (Karamanlidis et al. 2016b). Low genetic diversity is an important factor in the conservation of endangered species since it may, in combination with inbreeding depression, reduce fertility and increase infant mortality, thus resulting in a limited ability to cope with environmental change (Frankham 1995).

### Hybridization

There is no evidence of hybridization between the Mediterranean monk seal and any other seal species.

## Life History

### Reproduction

Attainment of sexual maturity in Mediterranean monk seals appears to differ between sub-populations and is likely dependent on population density and/or environmental factors (i.e., food availability). Originally, female Mediterranean monk seals were estimated to reproduce for the first time at the age of 5–6 years (King 1983). However, over the years this benchmark has been revised downwards, to 4 (Marchessaux 1989), 2.5 (Gazo et al. 2000b), and most recently to 2.1 years (unpublished data, CBD Habitat in Karamanlidis et al. 2016a); this is considered to be the lowest age band recorded for any phocid species. In contrast, in Madeira female Mediterranean monk seals have been recorded to attain sexual maturity at the age of six (Pires et al. 2020). Male Mediterranean monk seals in Madeira have been observed to mate for the first time in their seventh

year. Gestation in Mediterranean monk seals lasts approximately 9–11 months (Pastor and Aguilar 2003), after which one pup is born (King 1956). Females can give birth in successive years (Güçlüsoy and Savaş 2003b; Pastor and Aguilar 2003).

Pupping in the north-eastern Mediterranean monk seal subpopulation (e.g., in the Cilician Basin in Türkiye and in the Northern Sporades Islands in Greece) is fairly synchronous and usually occurs during autumn, with a peak during the months of October and November (Gücü et al. 2004; Dendrinos 2011).

## Habitat and Diet

### Habitat Selection and Movement

Historical evidence suggests that Mediterranean monk seals used to haul out on open beaches (Johnson and Lavigne 1999; Johnson 2004; González 2015). Continuous human persecution however is believed to be the main factor that forced the species to occupy increasingly marginal habitat (Johnson and Lavigne 1999; Johnson 2004). Nowadays, Mediterranean monk seals inhabit cliff-bound coasts throughout their range where they use secluded marine caves for hauling out, resting, and pupping. Pupping in caves is not ideal, as pups might become separated from their mothers during storms and either drown or starve to death. Increased pup mortality due to pupping in suboptimal habitats has been recorded in the monk seal colonies of Cabo Blanco and Madeira (González et al. 2002; Pires et al. 2020; Fernandez de Larrinoa et al. 2021). When present, mothers try to protect their pups from being washed away by guiding them to the upper zone of the beach, or by interposing their bodies between the pup and the waves (Pires 2004; Karamanlidis et al. 2021). The use of suboptimal habitats for reproduction as an adaptation to human pressure has also been observed in other pinnipeds. [e.g., Guadalupe fur seals *Arctocephalus townsendi* (Bernardi et al. 1998)]. In areas where conservation measures are in place and/or human disturbance is low (e.g., the protected areas at Cabo Blanco, the Desertas Islands Nature Reserve), monk seals may haul out on open beaches; on certain occasions even births on open beaches have been recorded (Pires and Neves 2000; Fernandez de Larrinoa et al. 2007). Since 1993, there have been six records of female Mediterranean monk seals and their pups on open beaches in Greece. (Fig. 5) (Dendrinos et al. 2022).

Most marine caves currently used for resting and pupping by Mediterranean monk seals in the north-eastern Mediterranean Sea (Fig. 6) possess a set of common, geophysical features that include one or more entrances above or below water level, an entrance corridor, an internal pool and a dry surface or area, where the seals haul out (Dendrinos et al. 2007b). Selecting a cave for resting or pupping is influenced by these parameters (Karamanlidis et al. 2004; Dendrinos et al. 2007b). The frequency and intensity of cave use in the eastern Mediterranean is highest in autumn and winter, during the peak pupping season of the species (Gücü et al. 2004; Dendrinos 2011). Cave use may also be influenced by changes in the internal morphology of a cave (González et al. 1997), the state of the tide (Pires et al. 2007) or the wave strength and direction (Gücü et al. 2004; Dendrinos 2011). In the north-eastern Mediterranean Sea hundreds of such marine caves have been identified to be occupied by monk seals (Gücü et al. 2004; Dendrinos 2011; Dendrinos et al. 2020). The size of the interior dry surface in the marine caves in the north-eastern Mediterranean Sea appears to be a limiting factor in accommodating larger aggregations of the species. Furthermore, climate change and its possible effects (e.g., sea level rise) in the north-eastern Mediterranean may negatively affect the quality of the pupping habitat of the species.

### Feeding

Being capable of easily exploiting various food sources, Mediterranean monk seals have often been described as opportunistic predators (Marchessaux and Duguy 1977; Boutiba and Abdelghani 1997). Research throughout the monk seal's distribution indicates that the species has a

**Fig. 5** Image from a drone of two female Mediterranean monk seals and three pups using an open beach at an undisclosed location in Greece. © Panagiotis Dendrinos/MOm

**Fig. 6** Interior of a characteristic marine cave used by Mediterranean monk seals for resting and pupping in Greece. © Panagiotis Dendrinos/MOm

heterogeneous diet consisting of cephalopods (the common octopus *octopus vulgaris* is the most frequent prey item), bony fish (mainly from the family Sparidae), and crustaceans (Salman et al. 2001; Karamanlidis et al. 2011; Pierce et al. 2011; Kıraç and Ok 2019). For example, more than 70 prey species have been found in the stomachs of deceased monk seals in Greece (Pierce et al. 2011), while at the island of Zakynthos (Margaritoulis et al. 1996) and in Türkiye

(Tonay et al. 2016) they have been recorded preying on loggerhead sea turtles *Caretta caretta* and green sea turtles *Chelonia mydas*. Collectively, results from stomach contents (Salman et al. 2001; Karamanlidis et al. 2011; Pierce et al. 2011) and stable isotope analysis (Karamanlidis et al. 2014) suggest that Mediterranean monk seals in the north-eastern Mediterranean feed primarily on the continental shelf along the coast. When a fish is caught, the prey is often eviscerated first, with the seal moving its head violently to the side while holding it, and then it is ingested head first. (Duguy and Marchessaux 1992).

## Behavior

### Social Behavior

Although poorly understood, the social behavior of Mediterranean monk seals appears to be influenced by the moderate polygyny that is characteristic of the species (Gücü et al. 2004). As a consequence, adult males display territorial behavior, both in the area of the main pupping sites and in other areas as far as 30 km away (Gücü et al. 2004). Social interactions between adult males occur mainly underwater while defending these aquatic territories (Marchessaux and Muller 1987; González et al. 1997).

### Mating and Reproductive Behavior

Mating in Mediterranean monk seals occurs in the water (Pastor et al. 1998). Prior to parturition, females often retreat to isolated areas within the pupping caves where they try to fend off other approaching monk seals (Layna et al. 1999); aggressive interactions in the pupping caves between parturient females and between females and pups are not unusual (Dendrinos et al. 2007c; Karamanlidis et al. 2013). Female Mediterranean monk seals show a strong site fidelity to the most suitable pupping sites (Gazo et al. 1999). Fostering, even by non-filial females and milk stealing have been observed frequently (Karamanlidis et al. 2013). Interactions between mothers and pups during the early stages of a pup's life include numerous close contacts, either on land or at sea (Fig. 7). The weaning of the lactating pups occurs gradually, at 4–5 months of age (Dendrinos 2011), when pups begin to forage on their own (Kıraç and Ok 2019). Thus, females do not fast during the lactation period and leave their pups unattended for shorter or longer periods of time. (i.e., absences of up to 17 h have been reported) (Gazo and Aguilar 2005; Dendrinos 2011; Karamanlidis et al. 2021).

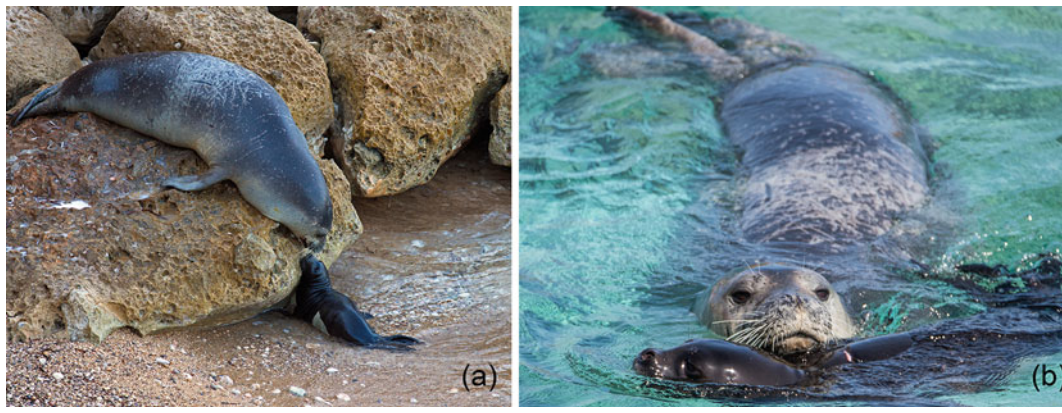


**Fig. 7** Interactions between mothers and pups in Greece. (**a**) © Panagiotis Dendrinos/MOm, (**b**) © Alexandros A Karamanlidis/MOm

## Communication

Communication among Mediterranean monk seals is still poorly understood. In many seal species, acoustic communication plays a major role in social interactions, and vocal signals convey important information about the emitter. Recent research in Greece on rehabilitating (Muñoz et al. 2011) and wild Mediterranean (Charrier et al. 2017) monk seals indicated the existence of five distinct call types (i.e., bark, chirp, grunt, short scream, and scream). The vocal signature of barks and screams is individually specific, thus providing the opportunity of developing new, passive acoustic monitoring systems based on individual identification.

## Activity

Compared to other pinnipeds, little information exists on the diving capacities and behavior of Mediterranean monk seals. Monk seal pups have been observed to enter the water already by the first week of their life (Karamanlidis et al. 2010; Karamanlidis et al. 2021), and their diving capacity increases gradually with age (Gazo et al. 2006; Dendrinos 2011). The maximum duration and depth of diving for one lactating female at Cabo Blanco were 15 min and 78 m (Gazo and Aguilar 2005); an adult male reached 100 m depth (unpublished data, CBD Habitat). Diving behavior of monk seals at Cabo Blanco, however, appears to be constrained by the topographic features of the marine environment in the region, as monk seals in the Mediterranean Sea (with much deeper waters than the Cabo Blanco region) have been recorded to dive for longer and to considerably greater depths. Maximum dive depths for a rehabilitated male and a female juvenile monk seal in Greece were 196 m (Dendrinos et al. 2007a) and 205 m (unpublished data, MOm), respectively. Monk seals in Greece have been recorded to travel long distances, for example ~288 km in 3 months, with a maximum straight distance traveled of ~78 km (Adamantopoulou et al. 2011). Recently, aquatic sleep has been documented for this pinniped species as well (Karamanlidis et al. 2017).

# Parasites and Diseases

## Parasites

Very little is known about the parasites of the Mediterranean monk seal. The following is a list of the parasites identified so far:

1. Lice (Phthiraptera): *Lepidophthirus piriformis* (Blagoveshtchensky 1966).
2. Roundworms (Nematoda): *Anisakis pegreffii* (Crety 1890), *Contracaecum* and *Paracoecum: Contracaecum* sp.; *C. osculatum*, *Terranoova decipiens* and *Anisakis pegroffi* (Campana-Rouget and Biocca 1955; Schnapp et al. 1962; Ronald 1973), *Acanthocheilonema spirocauda* (Papadopoulos et al. 2010).
3. Tapeworms (Platyhelminthes): *Diphyllobothrium elegans* (found at a monk seal caught at Senegal) (Markowski 1952), *Diphyllobothrium* sp., specifically *coniceps*, *elegans*, *lanceolatum*, *hians*, *latum*, and *Diplogenophorus tetrapteus*; *Bothriocephalus* sp., and an immature form under the name *Cysticerus cellulosae* (Schnapp et al. 1962; Ronald 1973).

## Infectious Diseases

So far, two morbilliviruses have been isolated from Mediterranean monk seals, one from a stranded animal in Greece and the other from carcasses washed ashore during a mass die-off in Mauritania. Genetic analysis showed that the monk seal morbilliviruses most closely resembled previously identified cetacean morbilliviruses, indicating that interspecies transmission from cetaceans to pinnipeds has occurred (van de Bildt et al. 1999; van de Bildt et al. 2000; van de Bildt 2001).

## Population Ecology

### Population Dynamics

Throughout the species' European distribution range, reproductive events are usually seasonal and show their highest concentration during the months of October and November (Pastor et al. 1998; Dendrinos et al. 1999; Güçlüsoy and Savaş 2003b; Gücü et al. 2004; Dendrinos 2011). The perinatal sex ratio does not appear to differ significantly from 1:1 (Gazo et al. 1999; Dendrinos 2011). In Greece, where only a small part of the entire coastline is systematically monitored (Fig. 8), an average of 75 newborn pups are recorded annually (unpublished data, MOm/Hellenic Society for the Study and Protection of the Monk Seal). The total Mediterranean monk seal population in the north-eastern Mediterranean Sea is estimated to number approximately 400–500 individuals.

### Competition with Other Marine Megafauna

The Mediterranean monk seal is the only seal species in the Mediterranean Sea. There is no indication of competition between monk seals and other species of marine megafauna for food sources, either in the scientific literature or any anecdotal accounts. However, there are records of Mediterranean monk seals preying upon loggerhead turtles (*Caretta caretta*) (Margaritoulis et al. 1996) and being preyed upon by Great white sharks (*Carcharodon carcharias*) (De Maddalena and Zuffa 2008; Pujol 2015).

### Effects of Climate and Environmental Change

For the Mediterranean monk seal, no direct effects of climate and environmental changes have been documented so far. Considering, however, that the effects of climate change in the north-eastern Mediterranean region (i.e., the main distribution area of the species) are expected to be particularly severe (Giannakopoulos et al. 2009), this potential threat to the survival of the species should not be ignored. Even a small rise in sea level due to climate change could be detrimental by making critical pupping habitat (i.e. marine caves) inaccessible to the species. Furthermore, environmental changes resulting in the arrival of Lessepsian marine species to the Mediterranean Sea could alter the feeding habits of the species.

## Conservation Status

The Mediterranean monk seal is listed in Appendix II of the Bern Convention, in Appendix I of the CITES Convention and Annex IV of the EU Habitats and Species Directive. Both, the global and the eastern Mediterranean populations of the species have been catalogued as "Endangered" in the IUCN Red List of Threatened Species (Karamanlidis and Dendrinos 2015; Karamanlidis et al. 2019). Following a partial population recovery the IUCN is now in the process of cataloguing the global and European population of the Mediterranean monk seal as "Vulnerable". The Mediterranean monk seal is also considered to be an Evolutionarily Distinct and Globally Endangered mammalian species (Isaac et al. 2007). In addition, national laws protect the species in all European countries where it currently occurs.

## Management

Historical sources indicate that over the centuries, human disturbance and persecution have driven the Mediterranean monk seal into increasingly marginal habitat – and continue to do so (Karamanlidis et al. 2016a). As a last resort, Mediterranean monk seals occupy nowadays secluded marine caves with an internal beach for resting and pupping. In some cases, even this bare minimum however is threatened by human activity (i.e., coastal development, recreational activities) and seals have been discovered inhabiting caves that are, in reality, little more than water-filled crevices. With no internal beach or haul out area, the animals rest or sleep while floating in the water


**Fig. 8** Image from an infrared camera used to monitor Mediterranean monk seals at the island of Makronisos in Greece, in 2018. © MOm

(Güçlüsoy and Savaş 2003b; Johnson 2004). It is believed that the colonisation of such marginal habitats has negative effects on the social behaviour of the species, its reproductive performance and the survival of the pup. (Gazo et al. 2000a; Gücü et al. 2004). It has been suggested that the marginal cave habitat currently occupied by the monk seal might not be suitable for the survival of the species, and that recovery of the Mediterranean monk seal will require a partial return to open beaches (Sergeant et al. 1978). On a positive note, habitat conservation efforts seem to confirm that Mediterranean monk seals, when not disturbed, return to open beaches to rest, nurse their pups and perhaps even breed. (Dendrinos et al. 2022).

## Main Threats

Although slightly decreasing nowadays, deliberate killing is still a major threat to the survival of the Mediterranean monk seal in the north-eastern Mediterranean Sea. In most cases, artisanal fishers kill seals as a reaction to the damages monk seals cause to fish catches and fishing gear (Goedicke 1981). More recently, fish farm operators have also come into conflict with monk seals that raid their facilities, particularly where adequate protective netting has not been installed (Güçlüsoy and Savaş 2003a). Research in Greece suggests that deliberate killing has been a major source of mortality, accounting for 43% of the deaths of adult/juvenile animals (Androukaki et al. 1999). In Türkiye, 5 out of 22 seals found dead in 1995–2000 had been deliberately killed (Güçlüsoy et al. 2004).

Accidental entanglement in fishing gear is considered to have played a significant role in the extinction of the monk seal from several parts of the species' previous range (Johnson and Karamanlidis 2000). It still is an important mortality factor in the north-eastern Mediterranean Sea, affecting mostly recently weaned and juvenile, inexperienced animals (Veryeri et al. 2001; Karamanlidis et al. 2008; Kıraç et al. 2013), usually caught in static gear and discarded nets in coastal areas (Karamanlidis et al. 2020).

Other threats that could potentially affect the Mediterranean monk seal in the north-eastern Mediterranean include prey depletion, stochastic events and pollution. Although prey depletion has

been associated in the past with the plight of the Mediterranean monk seal (Kompanje et al. 2000; Salman et al. 2001), there is currently no scientific evidence that lack of food is a threat in the north-eastern Mediterranean. Stochastic events could potentially also have a detrimental effect on the conservation of the Mediterranean monk seal (Soulé 1987). Stochastic events that have negatively affected Mediterranean monk seals in the recent past include a toxic "red tide" caused by a dinoflagellate bloom (Reyero et al. 2000) and/or a morbillivirus (Osterhaus et al. 1998) that led to a mass die-off in the Cabo Blanco in Mauritania/Western Sahara that eliminated two thirds of the entire population (Aguilar et al. 1998), rockslides and cave collapses (González et al. 1997; Panou et al. 2002), and a severe winter cold in the mid-1950s in the Black Sea (Berkes et al. 1979). Pollution is also considered a potential threat to the Mediterranean monk seal and is partly responsible for the species' plight (Sergeant et al. 1978; Boutiba 1996). This is still true in some cases, as the accumulation of pelagic oil and/or trash in coastal areas has made some marine caves unsuitable for resting and/or pupping (Kıraç 1998). Furthermore, organochlorine compound levels in monk seals living in the Mediterranean are considered to be high (Borrell et al. 1997). In contrast, trace element levels in Mediterranean monk seals in the north-eastern Mediterranean Sea are in general low and within the non-acutely toxic levels for seals (Formigaro et al. 2016). Because of the far-reaching implications that pollution may have on the health status of the entire marine ecosystem in general and the Mediterranean monk seal in particular, it is advised that its effects are continuously monitored.

## Priority Conservation Measures

During the last three decades, significant efforts have been made towards the effective protection of the endangered Mediterranean monk seal. In all areas [e.g. the eastern Atlantic (CMS 2005), Mediterranean Sea (Notarbartolo di Sciara 2013)] and in countries with significant monk seal populations [e.g. Greece (Dendrinos et al. 2020), Türkiye (Kıraç et al. 2013)] policy-makers and conservationists have drafted and have been implementing, with varying degrees of vigor and commitment, Action Plans for the conservation of the species.

There is a general consensus among conservation practitioners for the Mediterranean monk seal that in situ conservation efforts are the most important conservation priority for the species. The main in situ conservation priorities and actions identified up to date are: habitat protection; mitigating negative interactions between monk seals and fisheries; scientific research and monitoring of local seal subpopulations; education and public awareness campaigns; and rescue and rehabilitation of wounded, sick, and orphaned seals.

Habitat protection has been identified as the most important conservation priority for the Mediterranean monk seal. Considering the behavior and ecology of the Mediterranean monk seal, conservationists believe that a network of well-managed and efficiently guarded sites/reserves are essential and are the foremost priority for the survival of the species (Adamantopoulou et al. 2000). Legislative measures, research, management, and conservation actions designed to protect important monk seal habitat are currently in place in different areas identified as important monk seal pupping sites, such as: the Desertas Islands Nature Reserve in the Madeira Archipelago, the National Marine Park of Alonnisos – Northern Sporades Islands, the marine protected area in Northern Karpathos – Saria and the 3-mile no-take zone at the island of Gyaros in Greece, the no-fishing area of the Cap Blanc Peninsula, and the participative reserve that has been created in order to protect the pupping caves of the Cabo Blanco monk seal sub-population. In Türkiye, conservation efforts focus mainly on five coastal locations in the country: Foça, Karaburun, Alaçatı-Sigacik, the Bodrum Peninsula, and the Cilician coasts, though serious concerns have been raised about the efficacy of management and implementation (Kıraç et al. 2013). Suitable monk seal habitat currently under effective protection is considered substantially inadequate, and additional marine protected areas are necessary to secure the survival of the species, especially in countries

such as Greece and Türkiye where suitable habitat is still available. In Greece, a country that due to its exceptional geomorphology (long and complex coastline, thousands of islands and islets, numerous marine caves) hosts the core monk seal population in the Mediterranean, the majority of known pupping sites have already been included in the NATURA 2000 network (Adamantopoulou et al. 2022). This is a positive step towards the conservation of the species in the region. At the same time the lack of well-organized, long-term management schemes in most of these areas is an existing problem that has to be solved promptly. In general, the ineffective management of important marine protected areas for the species in many countries is a problem that has been already underlined more than a decade ago (Johnson et al. 2006).

Mitigating negative interactions between monk seals and small scale fisheries has been the focus of concerted conservation actions throughout the species' range (Karamanlidis et al. 2008; Hale et al. 2011; González and Fernandez de Larrinoa 2012; Karamanlidis et al. 2020). In Madeira, a clean-up operation, in combination with efforts to persuade local fishermen to change fishing gear (cease the use of static nets), effectively solved the problem of accidental entanglement (Neves 1991). As a result, the effects of negative interactions between monk seals and fisheries in the archipelago of Madeira were considered to be comparatively less than in other parts of the species' range (Hale et al. 2011). In Greece, where negative interactions between monk seals and fisheries are considered to be a serious threat to the species' survival, research efforts to understand the effects of such interactions have gone hand in hand with conservation efforts and have resulted in the formulation of a relevant Action Plan (Anonymous 2009). Recently, a scientific publication based on extensive efforts to interview artisanal fishers throughout the country summarized all available knowledge on this complicated issue and proposed specific measures to the relevant national and European authorities (Karamanlidis et al. 2020). Research and environmental activities with fishers and aquaculture operators have been carried out also in Türkiye (Güçlüsoy and Savaş 2003a; Güçlüsoy 2008).

Rescue and rehabilitation of wounded, sick, and orphaned seals has been and still remains an integral part of all monk seal conservation programs, and has been carried out with varying degrees of effort and success in Greece, Türkiye, Madeira, and Cabo Blanco (Neves and Pires 1998; Vedder et al. 1998; Androukaki et al. 2003; Anonymous 2007). The longest-standing program is the one running in Greece since 1990. So far, more than 35 orphan and/or sick and wounded monk seals have been treated, of which, 20 have been successfully released back into the wild. Apart from its contribution in rescuing a significant number of animals, the rescue and rehabilitation program of monk seals in Greece has contributed to the awareness and sensitization of the general public.

This rescue and rehabilitation program in Greece has been combined with a well-organized, citizen science project, the Hellenic Monk Seal Rescue and Information Network (HMSRINT) that is used in the real-time monitoring of the species on a national scale. Its operation is based on the voluntary participation of more than 2500 members from all over coastal Greece (i.e., members include coastal municipalities, local Port Police authorities, fishermen's cooperatives, veterinary authorities, and environmentally aware citizens) that collect essential biological information on the species.

The information collected through the HMSRINT is used to fine-tune the design and implement effective conservation and management measures for the Mediterranean monk seal in Greece. Based on information that has been collected through the HMSRINT a significant recovery of the range of the Mediterranean monk seal in Greece has been confirmed (Adamantopoulou et al. 2022). In addition, the HMSRINT allows the detection of mass mortality events and enables the response in emergency cases, e.g., when sick, wounded, or orphan monk seal pups are found and require human assistance to survive. Similar networks to the HMSRINT of Greece are currently operating effectively in Türkiye (Kıraç et al. 2013) and

Cyprus (Nicolaou et al. 2019) and are being set up in countries where the species is re-occurring (i.e., Albania) or is hoped to do so soon (e.g., Montenegro, Croatia) (Eastern Adriatic Monk seal Project 2019).

Currently, research and monitoring of monk seal subpopulations and education and public awareness campaigns are, to a greater or lesser degree, implemented in all the main parts of the species' range, though much scope for improvement and expansion still remains.

## Future Challenges for Research and Management

Despite recent positive population trends in some of the most important sub-populations, the Mediterranean monk seal remains still, undoubtedly, one of the most endangered marine mammals on Earth. In recent years, important steps have been made in understanding the biology, ecology, and behavior of this elusive species and in protecting it through various conservation activities, but more needs to be done to safeguard its future. Priority research and management actions should include:

- Mapping and evaluating all the important/suitable pupping areas for the species
- Expanding and effectively managing and protecting the network of Marine Protected Areas for the Mediterranean monk seal
- Ongoing monitoring and managing, on a day-to-day basis, Mediterranean monk seal populations that are outside protected areas, using Rescue and Information Networks (such as the ones operating in Greece, Cyprus, and Türkiye)
- Successful rehabilitating and re-introducing sick, wounded, or orphan Mediterranean monk seals back into the wild
- Mitigating seal – fishery interactions through the activation of already documented and proposed fishery regulations and compensation measures
- Increasing public awareness and environmental sensitization through national and international campaigns
- Strengthening international cooperation for the scientific monitoring and successful management of the Mediterranean monk seal and enabling knowledge-transfer from countries with long-standing experience in the monitoring of the Mediterranean monk seal (e.g., Greece) to areas where the species has been extinct and is most likely to re-establish itself in the near future

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