

## REVIEW

## The Mediterranean monk seal *Monachus monachus*: status, biology, threats, and conservation priorities

Alexandros A. KARAMANLIDIS\* *MOm/Hellenic Society for the Study and Protection of the Monk Seal, Solomou Str. 18, 10682, Athens, Greece. E-mail: akaramanlidis@gmail.com*

Panagiotis DENDRINOS *MOm/Hellenic Society for the Study and Protection of the Monk Seal, Solomou Str. 18, 10682, Athens, Greece. E-mail: p.dendrinos@mom.gr*

Pablo Fernández DE LARRINOA *Fundación CBD Habitat, Gustavo Fernández Balbuena, 2, 28002, Madrid, Spain. E-mail: pablo.fernandezdelarrinoa@cbd-habitat.com*

Ali Cemal GÜCÜ *Middle East Technical University, Institute of Marine Sciences, PK 28, 33731, Erdemli, Icel, Turkey. E-mail: gucu@ims.metu.edu.tr*

William M. JOHNSON *The Monachus Guardian, c/o M. Schnellmann, Wernerstr. 26, CH-3006, Bern, Switzerland. E-mail: editor@monachus-guardian.org*

Cem O. KIRAÇ SAD – AFAG, *Underwater Research Society – Mediterranean Seal Research Group, Akıncılar Sok. 10/1, Maltepe, Ankara, Turkey. E-mail: afag@sad.org.tr*

Rosa PIRES *Parque Natural da Madeira, Quinta do Bom Sucesso, Caminho do Meio, 9064-512, Funchal, Madeira, Portugal. E-mail: rosapires.sra@gov-madeira.pt*

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\*Correspondence author.

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### ABSTRACT

1. The Mediterranean monk seal *Monachus monachus* is the most endangered seal species. In this review we summarize the status, ecology, and behaviour of the Mediterranean monk seal, and identify the main threats that currently affect the species and the conservation priorities for securing its survival.

2. Once abundant throughout the Black Sea and Mediterranean, as well as off the Atlantic coasts of northwestern Africa and Macaronesia, the Mediterranean monk seal has recently suffered dramatic declines, both in abundance and geographical range. It is now estimated that fewer than 700 individuals survive in three or four isolated subpopulations in the eastern and western Mediterranean, the archipelago of Madeira and the Cabo Blanco area in the northeastern Atlantic Ocean.

3. Mediterranean monk seals are coastal marine mammals. When resting and pupping on land, individuals generally seek refuge in inaccessible marine caves; this behaviour is, in part, believed to be an adaptation to increased disturbance by humans. Larger aggregations or colonies of the species can now be found only at Cabo Blanco in the Atlantic Ocean and on the island of Gyaros in the eastern Mediterranean.

4. The main threats to the survival of the Mediterranean monk seal are habitat deterioration; deliberate killing, mainly by fishermen; and accidental entanglement and drowning in fishing gear. Limited availability of food sources and stochastic and unusual events have occasionally also contributed to Mediterranean monk seal mortality.

5. Based on a common consensus among scientists and conservationists, the main conservation priorities for the monk seal are: habitat protection; mitigating negative interactions between seals and fisheries; scientific research and monitoring of local seal populations; education and public awareness campaigns; and rescue and rehabilitation of wounded, sick, and orphaned seals.

## INTRODUCTION

The Mediterranean monk seal *Monachus monachus* is the sole representative of the genus *Monachus* (Scheel et al. 2014). The species was described for the first time in antiquity by Aristotle (Johnson & Lavigne 1999a), then in 1779 by Johann Hermann, who named the species *Phoca monachus* because of his belief that the name *moine* (monk) was in use colloquially in Mediterranean France, while at the same time remarking a visual resemblance to a hooded monk (Johnson 2004). Despite this early recognition, low population numbers, the inaccessibility of its habitat, and lack of coordinated efforts to study and protect the species resulted in the Mediterranean monk seal (hereafter also referred to simply as 'monk seal') remaining in scientific obscurity for the greatest part of modern history. When the first *in situ* research and conservation efforts were initiated in the late 1970s, the monk seal was already considered critically endangered (Ronald & Duguy 1979); poor understanding of the species' biology and ecology hampered its conservation (Johnson et al. 2006). In the past 25 years, however, research and conservation efforts have been carried out more systematically in the main distribution areas of the Mediterranean monk seal, greatly advancing our understanding of the species. The main aim in this review is to summarize the most important facts on *Monachus monachus* in the hope that it will constitute baseline knowledge to help guide future research and conservation efforts.

The uneven character of scientific information on monk seals has long complicated a thorough understanding of the species. While several studies on the Mediterranean monk seal are long-running and of high scientific value, others still exist only as 'grey literature'. This includes a number of studies that have not been formally peer-reviewed, such as academic dissertations, conference proceedings, etc. The information included in these studies is of variable quality, making it difficult to evaluate reliability. In this review, we have evaluated almost the entire existing literature on the species; most of the 'grey literature' has been excluded, although in some cases, we did use unpublished sources of essential information.

In this review we: (1) compile information on the distribution and status, biology, genetics, ecology, and behaviour of the monk seal; (2) identify threats likely to affect the survival of the species; and (3) identify the main conservation priorities and actions aimed at improving the chances of survival and recovery of the critically endangered Mediterranean monk seal.

## DISTRIBUTION AND STATUS

The Mediterranean monk seal is the only resident pinniped species in the Mediterranean Sea. Monk seals were once widely distributed throughout the Black Sea and Mediterra-

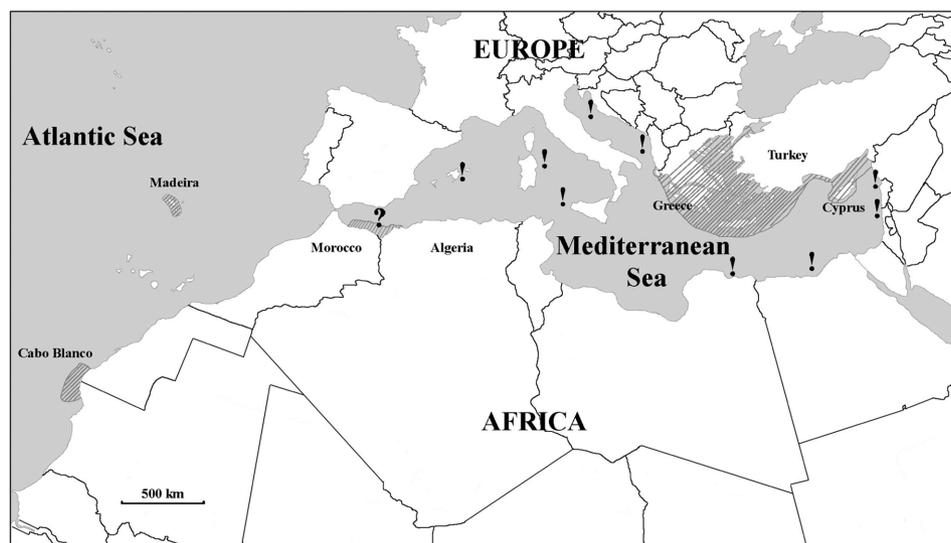
nean, and in North Atlantic waters from Cabo Blanco in the south to Morocco and northern Spain in the north, including the Azores, Madeira and the Canary Islands (Johnson et al. 2006, González 2015). Vagrants have been recorded in Senegal, the Gambia, the Cape Verde Islands, and Atlantic France, but the origin of these individuals is unknown (Johnson et al. 2006).

Monk seals have been exploited by humans since prehistoric times (Johnson & Lavigne 1999a, Johnson 2004, Stringer et al. 2008). Exploitation was particularly intense during the Roman era (Johnson & Lavigne 1999a) and in certain areas, such as the Madeira and Canary Islands and the Bay of Dhakla in Western Sahara, during the Middle Ages, when Mediterranean monk seals were commercially exploited (Israëls 1992, Johnson 2004, Brito 2012, González 2015). The species continued to be heavily persecuted by fishermen for most of the 20th century, which led to its disappearance from most of its former range.

The Mediterranean monk seal is currently considered to be the most endangered seal species in the world; its total abundance is estimated to be fewer than 700 individuals. The geographical range of the species is highly fragmented and there are three or four isolated subpopulations (Fig. 1).

In the Mediterranean, the species is found mainly in the sea's eastern reaches, around islands in the Ionian and Aegean Seas in Greece (Adamantopoulou et al. 1999), along the mainland coasts of Greece, Cyprus, and western and southern Turkey (Mursaloglu 1964, Gücü et al. 2004, 2009b, Güçlüsoy et al. 2004, Anonymous 2007b, Kiraç et al. 2013). In the Turkish Black Sea, monk seals are believed to be extinct since 1997 (Kiraç & Savas 1996, Kiraç 2011); some individuals still survive in the Sea of Marmara (Inanmaz et al. 2014). The eastern Mediterranean monk seal subpopulation is currently the largest, and is estimated to number fewer than 350 mature individuals (Güçlüsoy et al. 2004, Anonymous 2007b, 2008b, 2009a).

In the North Atlantic, two subpopulations exist: one at Cabo Blanco (also known as Cap Blanc) at the border of Mauritania and Western Sahara (González & Fernandez de Larrinoa 2012, Martínez-Jauregui et al. 2012), and one at the archipelago of Madeira (Pires et al. 2008). The Cabo Blanco monk seal subpopulation was estimated in the early 1990s to number 317 seals, but a mass mortality event in 1997 reduced the subpopulation by more than two-thirds (Forcada et al. 1999, Forcada & Aguilar 2000). Since then, the subpopulation has been showing encouraging signs of recovery: in 2013, 159 individual adult seals were identified and it is estimated that approximately 220 seals currently compose the second largest monk seal subpopulation (Martínez-Jauregui et al. 2012, unpublished data, Fundación para la Conservación de la Biodiversidad y su Hábitat; CBD Habitat). The third largest subpopulation is located in the archipelago of Madeira and numbers



**Fig. 1.** Map of the Mediterranean Sea and North Africa, indicating the current distribution of the Mediterranean monk seal and some of the locations cited in the text. Cross-hatched areas indicate the geographical range of extant monk seal populations; the question mark indicates an area where the fate of the population is unknown; the exclamation marks indicate areas outside the current range where Mediterranean monk seals have recently been seen.

approximately 40 monk seals (Pires et al. 2008, Pires 2011). Once almost extirpated and restricted to the remote Desertas Islands (Neves & Pires 1999), monk seals have recently begun to recolonize the main island of Madeira (Pires 2011), where suitable habitat for the species still exists (Karamanlidis et al. 2003).

An unknown number of monk seals might still survive along the Mediterranean coasts of eastern Morocco and perhaps Algeria (Mo et al. 2011), but without systematic monitoring, the status and fate of this subpopulation remains uncertain.

The monk seal populations at Cabo Blanco in the Atlantic (Martínez-Jauregui et al. 2012), and at Gyros Island in the eastern Mediterranean (Karamanlidis et al. 2013), are the only large extant aggregations of the species that still preserve the structure of a colony; the other subpopulations in the eastern Mediterranean are usually small, fragmented groups of <20 individuals.

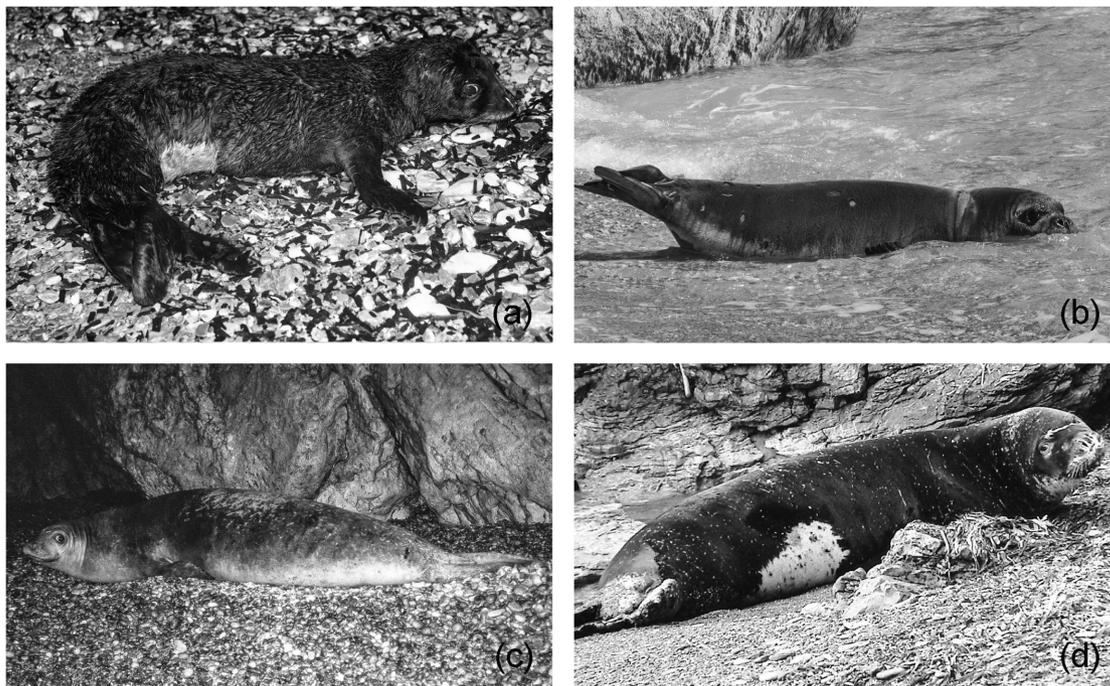
In recent years, sporadic extralimital occurrences of individual monk seals have been reported in countries where the species is considered to be effectively extinct, such as Albania (Anonymous 2012), Croatia (Gomerčić et al. 2011), Egypt (Di Sciara & Fouad 2012), Israel (Scheinin et al. 2011), Italy (Mo 2011), Lebanon (Anonymous 2010b), the Libyan Arab Jamahiriya (Alfaghi et al. 2013), Spain (Anonymous 2008a), and Syria (Abou-Zahra 2013). Without recurring sightings of different individuals, however, and ongoing, systematic monitoring and recovery efforts, the species should still be regarded as recently extinct in these countries.

## BIOLOGY

Mediterranean monk seals are medium-sized phocids (Gilmartin & Forcada 2002). In the Cabo Blanco subpopulation, the average length of female and male adults is 2.42 and 2.51 m, respectively. Average length at birth is approximately 1 m (range: 0.88–1.03 m) at both the Cabo Blanco and the monk seal subpopulation in the eastern Mediterranean (Marchessaux 1989, Samaranch & González 2000, Dendrinos 2011). Newborn pups weigh 15–26 kg and adults 240–300 kg; the maximum weights reported for the species are 400 kg for a male adult and 302 kg for a pregnant female (Sergeant et al. 1978, Boulva 1979, Marchessaux & Pergent-Martini 1991, Gilmartin & Forcada 2002, Dendrinos 2011).

Mediterranean monk seals are characterized by morphological differences between different development stages (González et al. 1996, Samaranch & González 2000). Male adults have an overall black pelage with a white belly patch, in contrast to female adults that are generally brown or grey with a lighter belly (Samaranch & González 2000, Dendrinos 2011; Fig. 2). In Madeira and Cabo Blanco, some subadults and adults have been recorded with a partially or completely whitish pelage (Pires 2011, unpublished data, CBD Habitat). Intense social and mating interactions often result in scarring on the throats and hind flippers of males and on the backs of females (Grau et al. 1994, Forcada & Aguilar 2000, Samaranch & González 2000).

Monk seal pups are born with a characteristic black to dark chocolate woolly coat (also known as 'lanugo' fur) and



**Fig. 2.** 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 the body; (b) a juvenile monk seal with a slim, elongated body and few external morphological characteristics (scars); (c) a female adult with a characteristic light brown or greyish pelage and numerous scars on the dorsal side of the body; (d) a male adult, showing the characteristic white patch on the ventral side of the body and numerous scars at the throat and hind flippers. Photos: (a, c) Panagiotis Dendrinis/MOM, (b, d) Alexandros A. Karamanlidis/MOM.

a white patch on the ventral side of the body (Badosa et al. 1998, Dendrinis 2011). The shape, size, and position of the patch, which is often spotted (Dendrinis 2011), varies between individuals and according to gender (Badosa et al. 1998). Juvenile and adult Mediterranean monk seals have very short and bristly hair [about 0.5 cm long; the shortest hair among pinnipeds (Ling 1970)], which lies close to the animal's body, thus forming a close-cropped pelt.

The neonatal moult follows a well-defined pattern (Androukaki et al. 2002) and occurs on average eight weeks post-partum (Badosa et al. 2006, Dendrinis 2011). This moult occurs partly in the water, may last one to three weeks (Mursaloglu 1986, Androukaki et al. 2002, Dendrinis 2011) and is not associated with weaning, as moulted monk seals have been observed to suckle (Gazo et al. 2006). Moulting of juveniles and adults occurs throughout the year (Androukaki et al. 1999, Güçlüsoy & Savaş 2003a, Pastor & Aguilar 2003); there appears to be no significant difference in the moulting period between monk seal subpopulations in the eastern Mediterranean and the Cabo Blanco region (Badosa 1998). Mediterranean monk seals shed their hair along with large layers of epidermis (Badosa 1998), partly in the water. A series of sequential moulting phases has been identified, including a long pre-moult phase (brown pelage)

and a post-moult phase (dull appearance). In the Cabo Blanco monk seal subpopulation, the intermoult period was close to one year except in females nursing a pup. Such females have longer intermoult periods and can even moult while still lactating (Pastor & Aguilar 2003). Development of the male adult pelage is gradual, involving usually two annual moults. This process is often completed by the age of four years (Badosa et al. 2006).

Male Mediterranean monk seals have been observed to mate for the first time in their seventh year. The earliest estimate of attainment of sexual maturity for a female Mediterranean monk seal was first reported to be five to six years (King 1983). Over the years, this has been revised downwards, to 4.0 (Marchessaux 1989), 2.5 (Gazo et al. 2000a), and most recently to 2.1 years (unpublished data, CBD Habitat); this is considered to be the lowest age band recorded for any phocid species. Mating in monk seals occurs in the water (Pastor et al. 1998).

After a gestation lasting approximately nine to 11 months (Marchessaux & Pergent-Martini 1991, Pastor & Aguilar 2003), one pup is born (King 1956). Females can give birth in successive years (Panou et al. 1993, Pires & Neves 2001, Güçlüsoy & Savaş 2003a, Pastor & Aguilar 2003). Prior to parturition, females often retreat to isolated areas within

caves and fend off other approaching monk seals (Layna et al. 1999). Aggressive interactions in the pupping caves between females and between females and pups are common (Dendrinis et al. 2007b, Karamanlidis et al. 2009, 2013).

## GENETICS

Genetic analyses of mitochondrial and nuclear DNA (Pastor et al. 2004, 2007, Karamanlidis et al. 2014b) have shown that, as a consequence of severe population bottlenecks and population fragmentation, all monk seal subpopulations exhibit low levels of genetic diversity. In fact, the mitochondrial DNA diversity of Mediterranean monk seals is among the lowest recorded in any pinniped species (Karamanlidis et al. 2014b). Low genetic diversity is an important factor in the conservation of endangered species as it may, in combination with inbreeding depression, reduce fertility and increase infant mortality, thus resulting in an endangered species' limited ability to cope with environmental change (Frankham 1995).

## HABITAT

Historical evidence suggests that Mediterranean monk seals once hauled out on open beaches (Johnson & Lavigne 1999a, Johnson 2004, González 2015). However, in more recent times throughout their range they frequent cliff-bound coasts where they use 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 die from starvation. It is believed that occupying such suboptimal habitat is partly a recent adaptation in response to human pressures (Johnson & Lavigne 1999a, Johnson 2004); similar behaviour has 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 activity is low (e.g. the protected areas at Cabo Blanco, the Desertas Islands Nature Reserve and the island of Gyáros in Greece), monk seals may haul out on open beaches; on certain occasions even births on open beaches have been recorded (Pires & Neves 2000c, Fernandez de Larrinoa et al. 2007, Dendrinis et al. 2008).

Most marine caves currently used by monk seals for resting and pupping possess a set of common geophysical characteristics, 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 (Dendrinis et al. 2007c). Monk seals' preferences regarding the use of a cave as a resting or pupping site are influenced by these parameters (Karamanlidis et al. 2004, Dendrinis et al. 2007c). 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, Dendrinis 2011). Cave use may also be influenced by changes in the internal morphology of a cave (e.g. in Cabo Blanco; González et al. 1997), the state of the tide (e.g. in Madeira; Pires et al. 2007) or the wave strength and direction (e.g. in the eastern Mediterranean Sea; Gücü et al. 2004, Dendrinis 2011). A major difference in the terrestrial habitat of Mediterranean monk seals occupying Cabo Blanco and those occupying the rest of the species' range is the number of marine caves. Whereas in Cabo Blanco, the entire monk seal subpopulation uses a small number (<5) of neighbouring marine caves for resting and pupping (Marchessaux & Muller 1987, Francour et al. 1990, González et al. 1997, Martínez-Jauregui et al. 2012), in the archipelago of Madeira and in the eastern Mediterranean, monk seals may occupy dozens or even hundreds of caves (Gücü et al. 2004, Karamanlidis et al. 2004, Anonymous 2007b, 2008b, 2009a).

## PUPPING

Pupping in the monk seal colony at Cabo Blanco prior to the mass die-off in 1997 was observed throughout the year, with a small peak of births in September (Gazo et al. 1999, Pastor & Aguilar 2003). Following the mass die-off, a change in the reproductive parameters of the colony was observed (González et al. 2002) and currently births are recorded from April to November, with a clear peak in September (Cedenilla et al. 2007). Also, since the mass die-off, annual reproductive rates have increased from 0.25–0.43 to 0.76 pups per female adult; the annual pupping rate has also increased from 23 pups in 2000 to 69 pups in 2014 (Gazo et al. 1999, Gazo et al. 2000b, unpublished data, CBD Habitat). In all other parts of the species' range, pupping appears to be more synchronous. In the archipelago of Madeira, two to three pups are born annually, mostly during the months October and November (Pires et al. 2008). The same pupping season has been recorded in Turkey's Cilician Basin (Gücü et al. 2004) and in Greece (Dendrinis et al. 1994, 1999, Dendrinis 2011). In Greece, where only a small part of the entire coastline is systematically monitored, 40 newborn pups are recorded on average annually (unpublished data, Hellenic Society for the Study and Protection of the Monk Seal; MOm).

During the lactation period, females leave their pups unattended for periods of on average nine hours in order to forage, although absences up to 17 hours have been reported (Gazo & Aguilar 2005). Fostering and milk stealing are common (Pires 2004, Aguilar et al. 2007, Karamanlidis et al. 2013). Some pups in the Cabo Blanco subpopulation have been fostered long-term by unrelated females (Aguilar et al. 2007). Weaning of pups occurs at four to five months

of age (Pastor & Aguilar 2003, Aguilar et al. 2007, Dendrinos 2011). At this time, pups begin to forage on their own (Pastor & Aguilar 2003).

## DIVING

Compared with other pinnipeds, little information exists on the diving capacities and behaviour of Mediterranean monk seals. Monk seal pups may enter the water already by the first week of their life, and their diving capacity increases gradually with age (Mursaloglu 1986, Gazo et al. 2006, Karamanlidis et al. 2010, Dendrinos 2011). At the end of lactation, pups at Cabo Blanco are already capable of spending approximately three minutes at a depth of more than 10 m (Gazo et al. 2006). The maximum duration and depth of diving for one lactating female at Cabo Blanco was 15 minutes and 78 m (Gazo & Aguilar 2005); a male adult reached 100 m depth (unpublished data, CBD Habitat). Diving behaviour 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 (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. While foraging, monk seals in Madeira and Turkey have been recorded to dive for on average five to seven minutes (Neves 1998, Kiraç et al. 2002); the longest dive recorded was 18 minutes (Kiraç et al. 2002). Monk seals in Greece have been recorded to travel long distances, for example ~288 km in three months, with a maximum straight distance travelled of ~78 km (Adamantopoulou et al. 2011).

## FEEDING

Mediterranean monk seals have often been described as opportunistic predators (Marchessaux & Duguy 1977, Boutiba & Abdelghani 1997) because of their ability to exploit various food resources easily. Studies throughout the monk seal's range have revealed that the species has a heterogeneous diet consisting of bony fish (mainly from the family Sparidae), cephalopods (the common octopus *Octopus vulgaris* is the most frequent prey item), and crustaceans (Marchessaux 1989, Neves 1998, Salman et al. 2001, Karamanlidis et al. 2011, Pierce et al. 2011, Muñoz Cañas et al. 2012). In Greece, more than 530 prey species have been found in the stomachs of deceased monk seals (Pierce et al. 2011); at the island of Zakynthos monk seals have been recorded preying on loggerhead turtles *Caretta caretta* (Margaritoulis et al. 1996). Collectively, results from stomach contents analysis (Marchessaux 1989, Neves 1998,

Salman et al. 2001, Karamanlidis et al. 2011, Pierce et al. 2011, Muñoz Cañas et al. 2012) and stable isotope analysis (Pinela et al. 2010, Karamanlidis et al. 2014a) suggest that monk seals feed primarily on the continental shelf along the coast. When a fish is caught, the prey is often first eviscerated by the seal making violent sideways movements of the head while holding it, and then it is ingested headfirst (Duguy & Marchessaux 1992, Anonymous 2004).

## THREATS

The Mediterranean monk seal is one of the most endangered (Anonymous 2010a) and one of the most Evolutionarily Distinct and Globally Endangered (EDGE; Isaac et al. 2007) mammalian species. The intensity or importance of the various threats to the species may vary regionally, but a consensus of scientific opinion considers the following often interrelating factors serious threats to the species' survival: increased human encroachment leading to destruction, alteration and fragmentation of suitable monk seal habitat; continued mortality because of deliberate killing by humans, and fisheries by-catch.

Habitat deterioration, destruction, and fragmentation have played and continue to play significant roles in the plight of the Mediterranean monk seal. Once an open beach dweller, the species has been heavily persecuted by humans and forced to occupy inaccessible marine caves. The gradual process from occupying open beaches to being displaced and forced into increasingly marginal habitat has been thoroughly documented (Johnson & Lavigne 1999b, González 2015). Occupation of such habitat is considered to be the driving force behind the low pup survival rates that have been recorded in some pupping areas (Gazo et al. 1999, 2000b, Gücü et al. 2004). Newborn pups may be washed away by waves surging into the caves, and may either drown or be separated from their mothers, subsequently dying from starvation (Neves & Pires 2001). Habitat deterioration is an ongoing threat, particularly in parts of the eastern Mediterranean, such as Turkey, where monk seals have been observed to occupy marine caves without an internal beach or haul-out area so that they must rest while floating in the water, and where declines in pupping success have been recorded (Güçlüsoy & Savaş 2003a, Anonymous 2007b, Gücü et al. 2009a, Notarbartolo di Sciara et al. 2009, Kiraç et al. 2013). In these areas, critical monk seal habitat has been also affected by increased tourism activities (Johnson & Lavigne 1999b). 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).

One of the most important threats to the survival of the species, deliberate killing, is an illegal act usually committed

by fishermen. Angered over actual or perceived damage caused by monk seals, including loss of catch and tearing of nets, fishermen take the offensive by shooting seals, or even in the past by dynamiting caves (Goedicke 1981). Deliberate killing of Mediterranean monk seals by fishermen has been a serious threat to the species in Greece, Turkey, and Cabo Blanco. Deliberate killing was responsible for a third of the mortalities recorded between 1991 and 1995 in Greece, affecting mostly adult monk seals (Androukaki et al. 1999), and has played an important role in the decline of the population of the species in Turkey (Güçlüsoy et al. 2004, Kiraç et al. 2013). In the Cabo Blanco region, deliberate killing, mainly by fishermen, may well have been responsible for the extirpation of monk seal populations hauling out on open beaches (González & Fernandez de Larrinoa 2012).

Interactions between monk seals and fisheries are a great conservation concern throughout the species' range (Güçlüsoy & Savaş 2003b, Güçlüsoy 2008, Karamanlidis et al. 2008, Hale et al. 2011, González & Fernandez de Larrinoa 2012). Mediterranean monk seals can become entangled in static nets (Johnson & Karamanlidis 2000), and accidental entanglement and drowning is a major source of mortality in the eastern Mediterranean, especially for subadult animals (Ververi et al. 2001, Karamanlidis et al. 2008, Kiraç et al. 2013). Similarly, at Cabo Blanco illegal industrial and artisanal fishing is one of the main threats to the survival of the colony; it mainly affects subadult monk seals (González & Fernandez de Larrinoa 2012).

Although limited availability of food and stochastic and unusual events are acknowledged as mortality factors affecting the Mediterranean monk seal, they are not generally considered to constitute serious threats to the survival of the species. Overfishing, which may affect seals' growth, reproduction, juvenile survival and mortality rate, and drive monk seals away from their natal areas (Israëls 1992), has been implicated in the local disappearance of monk seals in Algeria (Boudouresque & Lefevre 1988), Greece (Marchessaux 1979), and southern Turkey (Gücü et al. 2004). Stochastic events can also have a serious impact on the survival of an endangered species (Soulé 1987) such as the Mediterranean monk seal. Stochastic and unusual events that have caused monk seal mortality in the past include toxic algal blooms (Costas & Lopez-Rodas 1998, Hernández et al. 1998, Reyero et al. 2000), predation by sharks (Pujol 2015), virus outbreaks (Osterhaus et al. 1998), rock slides and cave collapses (Panou et al. 1993, González et al. 1997), and abnormally low sea temperatures (Berkes et al. 1979).

## CONSERVATION PRIORITIES AND ACTIONS

The Mediterranean monk seal is protected by legal statute throughout its range through numerous national laws,

regional and international treaties, and European Union regulations (Israëls 1992). Currently, in all areas [e.g. the eastern Atlantic (González et al. 2006), Mediterranean Sea (Notarbartolo di Sciara 2013)] and countries [e.g. Greece (Notarbartolo di Sciara et al. 2009), Turkey (Kiraç et al. 2013)] with significant monk seal populations, policy-makers have drafted and are implementing, with varying degrees of vigour and commitment, Action Plans for the conservation of the species. There is a general scientific consensus that *in situ* conservation efforts are the most important conservation priority for the monk seal. The main *in situ* conservation priorities and actions identified in these Action Plans 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 behaviour and ecology of the monk seal, conservationists believe that, in Greece, a network of well-managed and guarded 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 the following areas: 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 subpopulation. In Turkey, conservation efforts focus on five coastal locations in the country: Foça, Karaburun, Alaçati-Sigacik, the Bodrum Peninsula, and the Cilician coasts, although serious concerns have been raised about the efficacy of management and implementation (Kiraç 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 Turkey where suitable habitat is still available. Because of management lapses or inadequacy, lack of funding, monitoring and guarding, coupled with indifferent support by local stakeholders, some potentially important monk seal reserves are currently deemed unfit for purpose, and a substantial effort will be required to remedy this (Johnson et al. 2006).

Mitigating negative interactions between monk seals and fisheries has been the focus of concerted conservation actions in all four main parts of the species' range

**Table 1.** Conservation priorities and actions for the critically endangered Mediterranean monk seal in the four main regions within the species' geographical range

| Region                                     | Conservation priorities   |   |  |
|--|---|---|--|
|  | Low   | Medium  | High   |
| Madeira*                                   | Monk seal rescue and rehabilitation   | Monitoring and mitigating negative human – seal interactions through public awareness and education campaigns<br>Maintaining cooperation between eastern Atlantic states in order to implement the 'Action Plan for the Recovery of the Mediterranean Monk seal in the eastern Atlantic'  | Habitat and species protection through enforcement of existing regulations<br>Scientific monitoring of the local monk seal population using non-invasive methodologies<br>Increasing public awareness and environmental sensitization  |
| Cabo Blancot                               | Monk seal rescue and rehabilitation   | Scientific monitoring of the local monk seal population<br>Increasing public awareness and environmental sensitization<br>Improving the legal framework of the Special Areas of Conservation for the Monk Seal<br>Maintaining cooperation between eastern Atlantic states in order to implement the 'Action Plan for the Recovery of the Mediterranean Monk seal in the eastern Atlantic' | Habitat protection through increased surveillance efforts in current and potential monk seal habitat<br>Promoting the increase in the geographical range of the Mediterranean monk seal at the west African coast<br>Reducing pup mortality by promoting the reoccupation of open beaches as pupping habitat<br>Reducing negative seal – fishery interactions through enforcement of fishery regulations |
| Greece‡ – eastern Mediterranean population | Monk seal rescue and rehabilitation<br>Establishment and operation of a national contingency plan to deal with exceptional or unusual monk seal mortality | Mitigation of seal – fishery interactions through enforcement of fishery regulations<br>Increasing public awareness and environmental sensitization   | Critical pupping habitat must be identified, legally protected and organized into a functional network of protected areas<br>Species monitoring through the continued operation of the Hellenic Rescue and Information Network   |
| Turkey§ – eastern Mediterranean population | Monk seal rescue and rehabilitation<br>Increasing public awareness and environmental sensitization<br>Prevention of marine pollution                      | Mitigation of seal – fishery interactions through enforcement of fishery regulations<br>Capacity building of authorities involved in monk seal conservation<br>Monitoring monk seal population status and threats for effective conservation  | Habitat protection through increased surveillance of important monk seal sites and establishment of Marine Protected Areas   |

\*The conservation priorities and actions for monk seals in Madeira are described in detail in the 'Action Plan for the recovery of the Mediterranean monk seal in the eastern Atlantic' (González et al. 2006).

†The conservation priorities and actions for monk seals in Cabo Blanco are described in detail in the 'Action Plan for the recovery of the Mediterranean monk seal in the eastern Atlantic' (González et al. 2006).

‡The conservation priorities and actions for monk seals in Greece are described in detail in the 'National Strategy and action plan for the conservation of the Mediterranean monk seal in Greece, 2009–2015' (Notarbartolo di Sciarra et al. 2009).

§The conservation priorities and actions for monk seals in Turkey are described in detail in the 'National action plan for the conservation of the Mediterranean monk seal *Monachus monachus* in Turkey' (Kıraç et al. 2013).

(Anonymous 2009b, Notarbartolo di Sciarra et al. 2009, Hale et al. 2011, González & Fernandez de Larrinoa 2012). In Madeira, a clean-up operation, in combination with efforts to persuade local fishermen to change fishing gear, 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 are considered to be comparatively less than in other parts of the species' range (Hale et al. 2011). In Cabo Blanco, efforts to understand the importance of monk seal – fisheries interactions (González & Fernandez de Larrinoa 2012) have been coupled with environmental education and capacity building with fishermen, in order to mitigate the negative effects of these interactions. 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 (Androukaki et al. 2006, Karamanlidis et al. 2008). From 2005 to 2009, the European Union funded a LIFE–Nature project focussed exclusively on mitigating the conflict between monk seals and fisheries in Greece; a relevant Action Plan was produced (Anonymous 2009b). However, the concrete conservation actions proposed in this Action Plan have not been implemented as yet, mainly because of financial constraints and limited political will to enforce relevant fisheries regulations. In Turkey, research (Güçlüsoy & Savaş 2003b, Güçlüsoy 2008) and environmental activities with fishermen and aquaculture operators have been carried out.

Rescue and rehabilitation of wounded, sick and orphaned seals is or has been an integral part of all monk seal conservation programmes, and has been carried out with varying degrees of effort and success in Greece, Turkey, Madeira, and Cabo Blanco (Neves & Pires 1998, Vedder et al. 1998, Androukaki et al. 2003, Anonymous 2007a).

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, although much scope for improvement and expansion remains.

The relative importance of the identified conservation priorities varies among the four main parts of the species' range (Table 1) because of differences in monk seal population dynamics, public acceptance of the species and available funding.

Despite recent positive population trends in some of the most important subpopulations, the Mediterranean monk seal remains one of the most endangered marine mammals on Earth. In recent years, important steps have been made in understanding the biology, ecology, and behaviour of this elusive species, but more needs to be done to safeguard the future of the Mediterranean monk seal. Priority conserva-

tion actions include additional research and monitoring of important monk seal subpopulations and the establishment of a functional network of marine protected areas that will protect critical monk seal habitat.

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