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## Demography and population structure of Northeastern Mediterranean monk seal population

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### Abstract

The Northeastern Mediterranean coasts that border southern Turkey host one of the last strongholds for the survival of the endangered Mediterranean monk seal (*Monachus monachus*, 1779). The seal colonies inhabiting south coast of Turkey have been studied since 1994 through various short-term research projects focusing on distinct small populations that were thought to be isolated. In this study, the entire extent of the area was monitored approximately for 3 years (between 2015 and 2018) with camera traps placed in 20 caves known to be actively used by the seals. A total of 7014 images taken throughout the study period, along with 25,100 images taken previously, were used to identify the seals inhabiting the area. In total, 37 individuals were identified based on the natural marks on the body. Based on photo-identified seals, a mark-recapture method was applied to estimate the total population size within the Northeastern Mediterranean. The overall population size was found to be 46 (SE=7.7) in the case of closed population and 53 (SE=34.8) in the case of open population during the study period. The range of identified seals was almost six times larger than previously documented in the same area, reaching distances up to 245 km. The population estimate indicated a decrease in population size compared to previous studies. Finally, the study emphasises the importance of long-term monitoring studies elucidating changes in the demographic parameters in relation to threats posed, rather than cut-paste measurement suggestions which are not applicable in reality, while structuring the conservation actions targeting survival of this highly endangered species.

**Keywords:** Mediterranean monk seal; Photo-id; Camera traps; Northeastern Mediterranean.

### Introduction

The endangered Mediterranean monk seal (Karamanlidis *et al.*, 2015) is one of the rarest pinniped species. Its overall population is estimated at approximately 700 individuals which principally inhabit the Eastern Mediterranean Sea and the North Atlantic waters of the Western Sahara and Portugal. This fragmentation has led to three geographically isolated populations, each of which are composed of extant subpopulations scattered in remote regions (Karamanlidis *et al.*, 2016). In contrast to the Cabo Blanco (Western Sahara) population, which preserves the structure of a colony (Martínez-Jauregui *et al.*, 2012), the Mediterranean subpopulations in the Mediterranean, with few exceptions, are usually small and fragmented (Karamanlidis *et al.*, 2016). It is also likely that some of these are transboundary, occupying the coastal waters of several countries (Mo *et al.*, 2003; Gücü *et al.*, 2009a; Scheinin *et al.*, 2011), thus making the estimation of population size and the monitoring of the species' conservation status, a complicated job.

Even though the species is protected through its in-

clusion in several international Conventions; (i.e. Bonn Convention on Migratory Species, Berne Convention of European Wildlife and Natural Habitats, CITES, SPA-BIO protocol of the Barcelona Convention) monk seal populations are at risk of extinction (Notarbartolo di Sciara & Kotomas, 2016). This situation draws attention to the importance of scattered small groups for the survival of species. In comparison to larger populations at the core of the distribution range of the species', the smaller populations at the geographic margin have higher chance of local extinction, as they experience difficulty to compensate temporal variability in demographic parameters due to small numbers of individuals, and might have risk of exposure to higher environmental instability (Holt *et al.*, 2005). These populations should be safeguarded because of their capacity to act as sources for recolonization into neighbouring areas. Therefore, sound population assessments capable of indicating population trends over time are crucial to determine the most urgent conservation measures. The Northeastern Mediterranean is believed to accommodate both, populations that have retained their reproductive ability as well as small isolat-

ed groups with uncertain vitality. The first comprehensive study of Cilician coast monk seals was conducted by Gücü *et al.* (2004). This was followed by surveys on the Adana-Antakya coastal stretch (Gücü & Ok, 2004), the Mersin- İskenderun region (Ok, 2006), the northern coasts of Cyprus Island (Gücü *et al.*, 2009a), and the coastal stretches of the Olympos-Beydağları (Gücü *et al.*, 2009b) and Kaş-Kekova (Gücü *et al.*, 2012) National Parks (see Fig. 1 for area names).

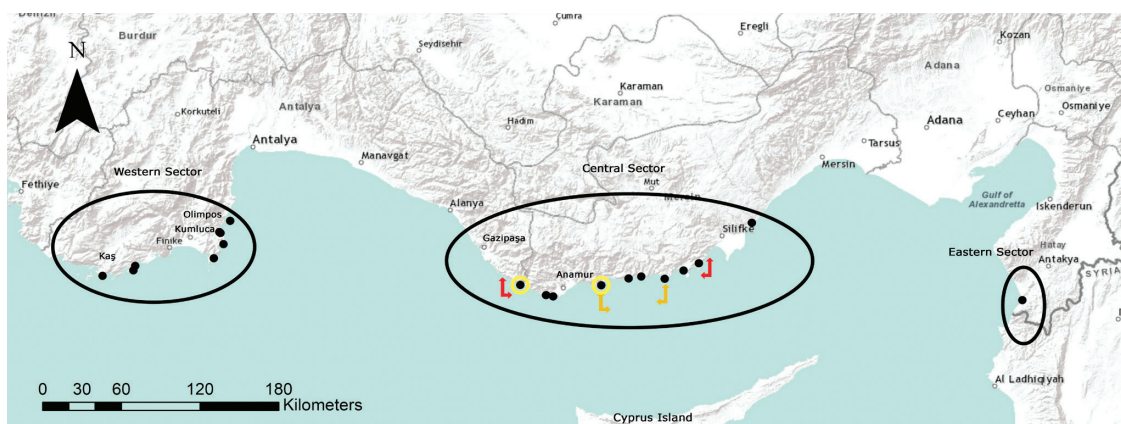
Critical issues regarding the Northeastern Mediterranean monk seal population in the Cilician coast dates back to 1994 when local fishers deliberately killed at least six seals (Gücü A, Personal communication, 2015 November). The first in situ monitoring studies conducted in the region revealed the urgency of setting concrete protection measures to relieve the plight of the species (Gücü & Erkan, 2005; Gücü *et al.*, 2004). Consequently, a set of conservation steps were taken, amongst which the designation of a 12 by 16 nautical miles marine fisheries restricted area in which industrial-scale fisheries were banned in 1999. For further protection measures involving the establishment of a coastal terrestrial belt surrounding the critical feeding, resting, and breeding habitats were designated in 1998 in order to deter human coastal modifications in the wider area. In 1999 two 1 by 0.1 nautical mile no-take-zones were also established encompassing the essential breeding caves (Fig. 1) (Gücü & Erkan, 2005). Ok (2006) compared the state of the seal population before and after the enforcement of the above mentioned conservation measures and demonstrated that the seals responded to the conservation actions positively, with significantly increased fecundity and survival rates. Moreover, a population viability analysis carried out in the same study, revealed that the probability of the population's abundance declining below the existent level at the year 2005 would have been 99% if conservation measures had not been enforced in the area (Ok, 2006).

In a similar study conducted in the west of the Cilician coast (Antalya) four seals were further identified (Gücü *et al.*, 2009b), and based solely on photo-identified seals, the size of the seal population in the Northeastern

Mediterranean was estimated as 42 individuals including individuals documented in the Cyprus Island (Gücü *et al.*, 2009a).

As Mediterranean monk seals use sheltered and isolated marine caves to haul out, population monitoring cannot be carried out through standard phocid visual survey techniques that rely on the visual observation of the seal haul-out sites from land, boat or air (Galatius *et al.*, 2015; OSPAR 2016). Moreover, due to its endangered status, and the species' sensitivity to human disturbance, Mediterranean monk seal studies require alternative non-invasive monitoring techniques. A common method used to overcome this challenge is the deployment of video/photographic cameras enabling high-resolution images to be obtained. Mo *et al.*, (2001) described the utility of using video cameras to monitor marine caves while Gücü (2009) investigated the effects of flash camera-trap deployment on the seals.

Use of video/photographic equipment in caves allows photo-identification of each individual seal based on distinguishable or unique patterns, scars, shapes, wounds and marks as demonstrated on other seal species (Hiby *et al.*, 2013). Photo-identification of monk seals was first described by Hiby & Jeffery (1987) in the Ionian Sea. Individual photo-identification through video/camera trap deployment has allowed the description of important monk seal life history traits such as pupping, lactation and moulting cycles (Gazo *et al.*, 1999; Forcada & Aguilar, 2000; Pastor & Aguilar, 2003; Badosa *et al.*, 2006) and to estimate population size through mark-recapture methods. Through such a method, Gücü *et al.*, (2004) provided the first population estimate of the monk seal population observed in the Cilician basin of Turkey. Another monk seal population estimate was further enriched by studies conducted to the west of the Cilician coast and until the northern coast of Cyprus (Gücü *et al.*, 2009a; Gücü *et al.*, 2009b). In these studies four individuals were further identified (Gücü *et al.*, 2009b), and based solely on photo-identification, the size of the seal population observed in the studied areas was estimated at 42 individuals (Gücü *et al.*, 2009a).



**Fig. 1:** The Northeastern Mediterranean study area with indication of the monk seal caves monitored between 2015 and 2018 (black dots). Red arrows indicate first degree natural asset, orange arrows indicate trawl and purse seine ban and yellow circles indicate ban to all means of exploitation).

Although the Turkish Northeastern Mediterranean coasts have been object of monk seal monitoring studies since 2003 (Gücü, 2003; Gücü *et al.*, 2004; Gücü & Ok, 2004; Ok, 2006; Gücü *et al.*, 2009a; Gücü *et al.*, 2009b; Gücü *et al.*, 2012), most of the studies conducted in the different subareas over time (the Antalya province, the Mersin province, the Antakya province, northern shores of Cyprus) do not allow compounding of the data into an overall population estimate. The latter however appears important to assess in light of the geographic continuity of the subareas and the linkages between the seals observed throughout the different studies (Gücü & Ok, 2004)

The present study aims to combine photo-identification data collected from the above mentioned surveys together with updated cave monitoring data collected simultaneously for the first time in the provinces of Antalya, Mersin and Antakya (Fig. 1). The objective is to provide an updated assessment of the Mediterranean monk seals inhabiting the wider area, while accounting for mobility and avoiding possible redundant identifications.

## Material and Method

### *Study Area, period and installation of monitoring equipment*

The study area was located in southern Turkey in the coastal sector extending over 569 km of coast located eastward from Kaş, in the province of Antalya, until the Turkish-Syrian border (Fig. 1). In this study area, previous studies have identified marine caves used by Mediterranean monk seals and also caves that met the requirements of a monk seal cave (IUCN/UNEP, 1988) based on the categories defined by Gücü *et al.*, (2004). Twenty nine (29) of these caves had been considered suitable for monitoring through the deployment of camera traps (Gücü *et al.*, 2003, 2004, 2009b). Caves considered suitable for monk seal monitoring amount altogether to 29 (Gücü *et al.*, 2003, 2004, 2009b) and 20 of these were selected for monitoring through camera trap deployment. The selected caves are distributed in the three most distant regions of the study area thereby hosting potential subgroups; seven caves located in the westernmost sector, twelve caves located in the central one, and one cave located in the easternmost sector (Fig. 1). The areas between these sectors mainly consist of sandy beaches, characterised by residential summer housing settlements or industrial development complexes which do not provide suitable monk seal habitat. Caves characterised by past rare seal use were excluded from the monitoring study. Field surveys for camera trap deployment, recovery, and maintenance began in October 2015 and ended in October 2018 in the central sector. Regarding the difficulty of accessing the distant caves, four surveys were conducted in the easternmost sector, and three surveys were conducted in the westernmost sector from 2017 to mid-2018. A total of 21 surveys were conducted to deploy equipment and retrieve data collected by the camera traps. Cameras were left activated until the next field survey. Durable lithium batteries

were used when time gaps were more than four months between surveys in order to guarantee continuous energy supply to the camera traps when time gaps between surveys were expected to be longer than four months. The central sector has been monitored from October 2015 to September 2018 using alkaline AA batteries.

Mediterranean monk seal caves were monitored with Bushnell Trophy Cam HD infrared camera traps to record the activities of seals throughout the study period. This model can detect heat and motion with its hyper passive infrared sensor (PIR) and motion sensor, respectively. Programmable PIR activation extends battery life and controls trigger intervals in case of motion detection. Moreover, information on time and date is included when recording the movements of the seals, which is beneficial for photo-id studies. The time interval between successive PIR activation triggering was set to 20 minutes precaution against possible deterrence driven by awareness of the cameratrap triggering (Gücü, 2009). Furthermore, to prevent over triggering due to other inhabitants of the caves, such as bats, birds, and mice, the sensitivity of the sensor was set to “low”. In order to have detailed information of marks, scars, wounds that will be used for identification cameras were operated in hybrid capture mode (one photo followed by a 30-second video recording). The cameras were mounted to the walls of the caves that allowed the best view of seal activity.

Additionally, caves with inner space that provided large areas to haul out were monitored with more than one camera trap. Up to 5 camera traps were mounted to a single cave to cover all possible haul-out platforms. Altogether, total of 27 camera traps were deployed in the 20 selected caves. When deciding on the placement of the camera traps, inner cave exposure to high waves due to extreme weather conditions was also considered.

### *Photo-Identification*

The images were sorted by date and time in order to prevent the misidentification of the individuals as they cannot be captured at the same time at two different caves. Physical characteristics of each individual, such as size, scars, natural marks, and unique patterns, were used as identification criteria (Marchessaux & Muller, 1989) and mapped to individual identification sheet which involves dorsal, ventral, lateral (right and left sides), anterior, and posterior drawings of the seal's body. Thus, once an individual identified, these sheets allowed us to evaluate the images showing small part of the body taken in different times and caves. Gücü & Ok (2004) reported that pelt colour changes while the animal dries during haul outs. Therefore, the colour was not used as an identification criterion.

### *Movement Distance Estimation*

The location of the caves where the individuals identified was recorded in order to evaluate the movement



distances of the seals. The mobility of identified seals was calculated using the “add path” facility of Google Earth pro (Google Earth, 2018) by adding paths among the caves visited by identified seal and measuring the distance of the paths.

### Population Size Estimation

A considerable effort was paid to monitor all possible seal haul-out areas of the seals in the study area. Considering that there might still be individuals who were not recorded during the study period, two models were used to estimate population size with a statistical significance figures. When seals inhabiting the coast of Mersin assumed to be a closed population, the Lincoln-Petersen closed population mark-recapture method with Chapman modification (Lancia *et al.*, 1994) was used to estimate the size of the population. In the other case, the population is assumed to be open, regarding the emigrations and immigrations that might occurred during the study period and Jolly-Seber model (Jolly, 1965; Seber, 1965) was utilized through R (R Core Team, 2013).

### Demographic Structure of the Colony

In order to assess demographic structure of the populations, photo identified seals were grouped into 12 categories, according to their sex and morphological stage based on adjusted morphological stages (Ok, 2006) compiled from previous studies (Scoullou *et al.*, 1994; Dendrinou *et al.*, 1999; Gazo *et al.*, 2000; Samaranch & Gonzalez, 2000) (Table 1). Moreover, age span of adult stages has been revised regarding the available information for Cilician population. Later, current minimum age of each identified individual was calculated. The lower limit of the morphological category (Table 1) that individual belongs to was used to calculate minimum age by adding elapsed time until the September 2018 to low end of the

morphological category. The photo-id data previously collected in the earlier studies carried out in the region were also utilized in order to determine the correct age of individuals (Gücü *et al.*, 2015; Ok, 2006). After the assessment of age and morphological states of photo captured seals, dead individuals were included in the table along with the date when the carcass was found. This data was further supported by searching for news and social media outlets to estimate a more accurate number of individuals. However, the majority of social media documents were not suitable for identification studies. Proper outlets only contained dead individuals that were used to cross-check identified seals and were included in demographic analysis.

### Results

A total of 25,100 images were captured by camera traps. Among them, 7,014 images contained evidence of seal presence.

A total of 36 individuals were photographed through cave monitoring activity and 34 of them photo-identified during the study period. A female seal without any distinguishable mark (coded as AnneX) and her pup (coded as PupX) remained unidentified. Among monitored individuals, one pup observed dead in the central sector and one pup (PupX) considered to be dead as it was observed only for one day in a single cave and was too young to move any other cave. Moreover, pups and mothers at the other caves were already identified and none of the identified seals matched the age criteria for PupX during the study period. In addition, five pups in the western sector which were reported as stranded dead on social media outlets are also included in the identification table in the bottom rows (Table 1). In total 34 alive individuals remained in the population the death seals are subtracted. One pup was observed dead through monitoring activities. The cause of death of the pups remains unknown as carcasses were detected by locals. However, five of these

**Table 1.** Modified morphological categories of the Mediterranean monk seal (after Samaranch & Gonzalez, 2000; Dendrinou *et al.*, 1999; Ok, 2006; Gazo *et al.*, 2000).

Stage	Characteristics	Period (Years)
1	Pre-moulted skinny pup	0.00-0.03
2	Fat pre-moulted pup	0.03-0.08
3	Moulting pup	0.08-0.14
4	Moulted pre-weaned pup	0.14-0.33
5	Weaned youngster	0.33-2.50
6	Sub-adult male	2.50-7.0
7	Young-adult male	7.0-10.0
8	Elder adult male	10.0-25.0
9	Sub-adult female	2.5-3.00
10	Young adult female	3.00-6.00
11	Elder adult female	6.0-25.0
12	Senescence age	20.0-

pup mortalities occurred directly after severe weather conditions took place in the region. The mortality rate of pups throughout the study was 0.25, 0.5, 0.2 for the years between 2015 and 2016, 2016 and 2017, 2017 and 2018 respectively with an average of 0.33 (S.D = 0.14) which is the highest observed mortality among age groups in this study. In fact, mortality was not observed at any other age groups. However, 11 seals that identified in the first year of the study have not been monitored again in the following two years.

Among the 34 alive individuals, six individuals were observed in the caves situated in the westernmost sector, 34 individuals were observed in the central one, and one individual was observed in the easternmost sector. Moreover, among identified seals, 3 adult female seals moved between the western and central groups. Assuming that the seals inhabiting the coast of Mersin is a closed population, therefore ignoring the dispersal to and from adjacent populations, the size of the population was estimated as 46 (SE=7.7) individuals, and the lower and upper confidence intervals varied between 35 and 88 (Petersen with Chapman modification). However, when it is assumed that the seals observed in Mersin are a part of an open population that immigrates to and immigrates from neighboring regions, the estimated population size increased to 53 (SE = 34.8). In this case, the confidence interval of the estimate also widens and the upper confidence limit of 95% rises to 121 (Jolly-Seber).

Mobility of all individuals varied from 16.3 to 245 km, where female mobility varied between 16.3 to 245 km, and male mobility ranged between 37.5 and 101 km. (Table 2).

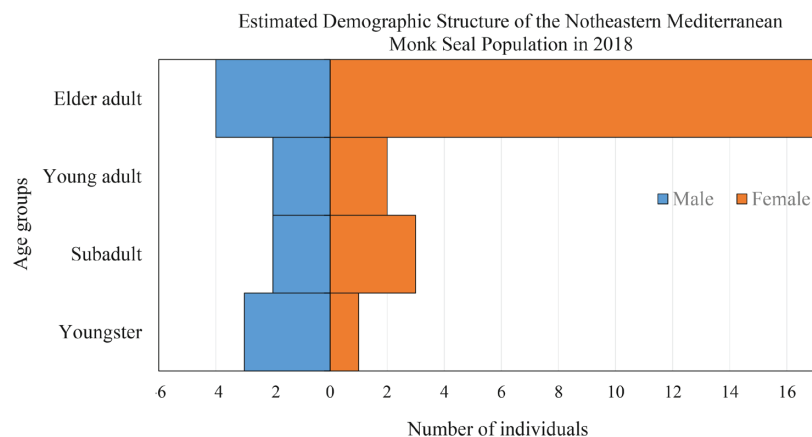
The male: female sex ratio at birth was 0.44: 0.56. However, based on information on the overall population (Fig. 2), the male: female ratio of the population was 0.39: 0.61 (11 males and 17 females). The demographic structure of the colony exhibiting alive individuals in 2018 is illustrated in Figure 2. The final estimate of the population based on compounded morphological categories

in Table 1, suggested that the study area in question accommodates three male youngsters, two sub-adult males, two young adult males and four elder males, one female youngsters, three sub-adult females, two young-adult females, and seventeen elder adult females.

## Discussion

When previous studies are taken into account, disregarding the seals inhabiting the Cyprus Island, the total number of identified seals in the present study is 34, which is four seals less than the number photo-identified nine years prior (Gücü *et al.*, 2009a; Gücü *et al.*, 2009b; Ok, 2006) Given that not all the haul-out sites were monitored, the difference demonstrated in this simple comparison might not be notably worrying. Nevertheless, it does not seem like, the estimate suggests that the population did not sustain the upward trend observed at the beginning of the 2000s after the implementation of the conservation measures.

The female-biased structure of the Northeastern Mediterranean population observed in the present assessment seems worrying. Previous studies (Ok, 2006; Gücü *et al.*, 2009b) estimated the male: female ratio for this population at 0.87 while the ratio currently observed is 0.33 (11 males and 23 females). Given that the sex ratio at birth is close to one, this skewed ratio observed in Figure 2, may possibly be the consequence of high mortality of males in some age classes. The high mortality rate observed at the early stages during the study, in general, is a matter of particular concern. Gazo *et al.*, (2000) estimated the mortality rate of pups leading to the first molting in Capo Blanco Peninsula as 0.63. This high mortality rate appeared to be related to adverse sea state, i.e., ocean swells and tides. Even though the current pup mortality rate observed in the Northeastern Mediterranean is lower than that observed in Capo Blanco, it is much higher than the rate (0.024) estimated for the period following the



**Fig. 2:** Estimated demographic structure of the colony. The figure shows existing morphological groups in 2018. The number individuals in each group has been assigned based on the classes in Table 1. Blue columns represent the male individuals, orange columns represent the female individuals.

**Table 2.** Identified Individuals with their maximum observed movement distances and ages. † represents the dead individuals from 2015 to 2018.

Sex	Estimated mobility	Name	Estimated age
M	101 km	Yamali	10.2
M	92.5 km	E4	8.7
M	78.5 km	Vitiligo	12.2
M	63.8 km	IkiNokta	13.3
M	-	Solciz	4.6
M	-	Yalniz	13.7
M	-	M1	8.2
F	16.3 km	Fuc	6.9
F	206 km	H fok	7.5
F	185 km	Karisik	8.2
F	-	Zehra	7.3
F	-	İzsiz	6.5
F	114 km	KAB	9.6
F	-	Kemik	8.1
F	114 km	Smiley	9.5
F	-	Vfok	8.4
F	-	Yfok	7.5
F	146 km	Ok	9.7
F	-	Annex	8.7
F	114 km	Tugra	11.4
F	-	U	9.3
F	245 km	X fok	8.6
F	-	Kucuk	6.1
F	-	Yay	7.5
F	25.4 km	Nenya	2.7
F	-	Yeni	3.5
F	-	Mgsboz2	3.4
F	151 km	A fok	2.8
M	37.5 km	Deniz	2.6
F	62.8 km	Recel	2.6
F	-	Kasik	1.5
M	-	Tufan	1.6
M	-	Yigit	1.4
M	-	Mustafa	2.5
F	-	Gazipasa †	0.40†
F	-	Umut †	0.31†
-	-	Pupx †	0.23†
-	-	Kemer †	0.08†
-F	-	Yatlimani1†	0.11†
F	-	Yatlimani2†	0.12†
-	-	Alanya †	0.01†
Total number of live adults			25
Total number of live pups			0
Total number of live immature individuals			9
Total number of live individuals			34

enforcement of the conservation measures 13 years earlier (Ok, 2006). Absence of pup group in the demographic table in 2018 on the other does not related with mortality rates but is due to breeding period of the seals did not coincide with ending of the study period.

The increased pup mortality is most likely associated with increasing threats, such as industrial constructions occurring in the area (Ok *et al.*, 2019), and with the increase in human disturbance generated by tourist activities in the Northeastern Mediterranean (Gücü, 2009b). Several camera-trap images documented large groups of human intruders systematically entering the caves. Besides, in several cases, tour boats were observed near the entrance of the caves during the regular surveys along the holiday season, which takes place before the breeding season of the seals. Although the high touristic season and the breeding season of the seals do not overlap, such disturbances continuously taking place in the proximity of breeding caves could have adverse impacts, particularly on the expectant seals using the area. It has been reported that increase in seal activity outside breeding caves prior to whelping season is likely associated with the female breeding preparation process (Gücü, *et al.*, 2004). It may, therefore, be speculated that an expectant female continuously disturbed in proximity to an elected breeding site, is forced to abandon the area to give birth in an alternative cave, and may abandon the area to give birth in an alternative cave, which may or may not be suitable for whelping. Moreover, continuous disturbances occurring after whelping might also weaken the mother-pup bond and further increase mortality before weaning. In such circumstances, this could explain the increased mortality rates observed in the early life stages. These results call for urgent actions to protect the species from expanding human pressure and to reduce the observed pup and presumed juvenile mortality so as to re-establish a more balanced demographic structure and sex ratio in the population.

The present study indicates that the mobility of seals is can reach a range of 245 km. This confirms previous observations of an adult injured female, traveling up to 280 km in Greece (Adamantopoulou *et al.*, 2011). Nonetheless, this particular individual had been treated twice for its injuries and observed in areas that were unusual for the species. Therefore, it was noted that injured and rehabilitated individuals might display atypical movements. Considering that knowledge over seal displacement has been limited by satellite telemetry studies on rehabilitated individuals and that wide area monitoring studies based on photo-identification are not yet uniformly distributed throughout the species range in the Mediterranean available information on wide ranging seal displacement capacity has often been undermined by the argumentation that it pertained to injured or rehabilitated individuals manifesting atypical movements. Our present study however, confirms that adult male and female seals, belonging to resident breeding populations object to monitoring and photo-identification studies, are capable of monk seal displacements up to 101 and 245 km in the Mediterranean. Until results are available from other

areas confirming these findings, we acknowledge that it remains to be verified whether the observed mobility may be a consequence of increasing pressures acting on the Northeastern Mediterranean breeding populations.

The noticeable decrease in cave use and number of individuals observed in the easternmost subarea, with respect to previous findings reporting the presence of 3 to 4 individuals between 2003-2005 (Ok, 2006), is alarming, and may be considered as a sign of disturbance induced displacement. In contrary to the decreased seal activities, increased monk seal sightings reported in nearby countries such as Syria (Mo *et al.*, 2003), Lebanon (Abou-Zahra, 2013; Anonymous, 2010), and Israel (Roditi-Elasar *et al.*, 2020; Scheinin *et al.*, 2011), where seals had been considered extinct for decades (Lavigne & Johnson, 2001), suggests that the individuals sighted in these previously unoccupied areas could be vagrants originating from the nearby Northeastern Mediterranean Turkish population

Additionally, a small group of seals consisting of <10 individuals was reported in Cyprus Island (Demetropoulos, 2011) with recent evidence of breeding activity (Marcou, 2015). In an earlier study conducted on the island, at least one of the seals photo-identified was previously observed on the Turkish coast, which evidenced the connectivity between the island and the mainland (Gücü *et al.*, 2009a). It is known that the recurrent emigration can increase the local abundance (Brown & Kadric-Brown, 1977) and reduce extinction risk (Stacey & Taper, 1992). On the other hand, immigration may also help the spread of pathogens, reduce fitness in the migrated population and increase extinction risk (Harding & McNamara, 2002). Therefore, potential connection between population in the Cyprus Island and population in the Turkish coast of Northeastern Mediterranean should be investigated carefully in order to design efficient management strategies.

On the whole, in light of the knowledge of the monk seal's distribution in the Mediterranean (Karamanlidis *et al.*, 2016), the individuals inhabiting the Northeastern Mediterranean in 2018 evidences the critical role of this population in terms of the species' survival in the easternmost part of the Mediterranean sea. However, when compared to earlier studies in the same area and considering the observed demographic structure, the results presented here highlight the need for urgent revision of currently applied conservation measures to protect the core (breeding) habitats reduce the observed pup and presumed juvenile mortality so as to re-establish a more balanced demographic structure and sex ratio in the population. The study provides evidence that the mobility of adult female and male monk seals is broader than postulated earlier. As suggested by Reijnders & Ries (1989), acquiring knowledge on dispersal and movement ability of the populations is a key component of the efficient management strategies targeting the protection of endangered species. Therefore regular long-term monitoring studies and conservation measures covering the entire extent of the prospective distribution range of the species, following harmonized methodologies, and linking threats with



mortality and fecundity of the population are of great importance.

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## References

- Abou-Zahra, A., 2013. Rare and pregnant monk seal falls victim to Arab instability. *International Fund for Animal Welfare*. <http://www.ifaw.org/unitedkingdom/news/rare-and-pregnant-monk-seal-falls-victim-arab-instability> (Accessed 10 April 2019).
- Adamantopoulou, S., Androukaki, E., Dendrinou, P., Kotomatas, S., Paravas, V. *et al.*, 2011. Movements of Mediterranean monk seals (*Monachus monachus*) in the eastern Mediterranean Sea. *Aquatic Mammals*, 37 (3), 256-261.
- Anonymous, (2010) Seal sightings in Lebanon. *The Monachus Guardian*. <https://monachus-guardian.org/wordpress/2010/09/12/seal-sightings-in-lebanon/> (Accessed 5 February 2019).
- Badosa, E., Pastor, T., Gazo, M., Aguilar, A., 2006. Moulting in the Mediterranean monk seal from Cap Blanc, Western Sahara. *African Zoology*, 41 (2), 183-192.
- Brown, J. H., Kodric-Brown, A., 1977. Turnover rates in insular biogeography: effect of immigration on extinction. *Ecology* 58 (2), 445-449.
- Demetropoulos, A., 2011. *National action plan for the conservation of the Mediterranean monk seal in Cyprus*. RAC/SPA, N20/RAC/SPA\_2011, 24 p.
- Dendrinou, P., Tounta, E., Kotomatas, S., 1999. A Field Method for Age Estimation of the Mediterranean Monk Seal Pups. 48. In: *13th Biennial Conference on the Biology of Marine Mammals, Maui, Hawaii, 28 November-3 December 1999*. Monachus Guardian, Greece (12.08.2019, <https://www.monachus-guardian.org/mguard06/06scien2.htm>).
- Forcada, J., Aguilar, A., 2000. Use of photographic identification in capture-recapture studies of Mediterranean monk seals. *Marine Mammal Science*, 16 (4), 767-793.
- Galatius, A., Ahola, M., Härkönen, T., Jüssi, I., Karlsson, O. *et al.*, 2015. *Guidelines for Seal abundance monitoring in the HELCOM area 2014*. HELCOM, 11 pp.
- Gazo, M., Layna, J. F., Aparicio, F., Cedenilla, M. A., González, L. M. *et al.*, 1999. Pupping season, perinatal sex ratio and natality rates of the Mediterranean monk seal (*Monachus monachus*) from the Cabo Blanco colony. *Journal of Zoology*, 249 (4), 393-401.
- Gazo, M., Aparicio, F., Cedenilla, M.A., Layna, J.F., González, L.M., 2000. Pup survival in the Mediterranean monk seal (*Monachus monachus*) colony at Cabo Blanco Peninsula (Western Sahara-Mauritania). *Marine Mammal Science*, 16 (1), 158-168.
- Gücü, A. C., 2003. The Cilician monk seal colony is growing. *The Monachus Guardian*, 6 (2), 51-53.
- Gücü, A.C., Erkan, F., 2005. A holistic approach for the conservation of the Mediterranean monk seal on the Cilician coast of Turkey. 1-11. In: *INOC International Workshop on Marine and Coastal Protected Areas. 23-25 March 2005, Meknes, Morocco*.
- Gücü, A.C., Ok, M., Orek, H., 2003. Seeking answers in the Gulf of Iskenderun: do eastern Mediterranean monk seals migrate. *The Monachus Guardian*, 6 (2), 54-56.
- Gücü, A.C., Ok, M., 2004. Arab the pilgrim. *The Monachus Guardian*, 7 (1), 1-4.
- Gücü, A.C., Gücü, G., Orek, H., 2004. Habitat use and preliminary demographic evaluation of the critically endangered Mediterranean monk seal (*Monachus monachus*) in the Cilician Basin (Eastern Mediterranean). *Biological Conservation*, 116 (3), 417-431.
- Gücü, A.C., 2009. Preliminary study on the effects of photo traps used to monitor Mediterranean monk seals *Monachus monachus*. *Endangered Species Research*, 10 (1), 281-285.
- Gücü, A.C., Ok, M., Sakinan, S., 2009a. A Survey of the critically endangered Mediterranean monk seal, *Monachus monachus* (Hermann, 1779) along the coast of Northern Cyprus. *Israel Journal of Ecology & Evolution*, 55 (1), 77-82.
- Gücü, A.C., Sakinan, S., Ok, M., 2009b. Occurrence of the critically endangered Mediterranean Monk Seal, *Monachus monachus*, at Olympos-Beydağları National Park, Turkey. (Mammalia: Phocidae). *Zoology in the Middle East*, 46 (1), 3-8.
- Gücü, A.C., Ok, M., Sakinan, S., Saydam, G., Akkuş, G., Kurmuş, N., 2012. *Kuzeydoğu Akdeniz Fok (Monachus monachus) Popülasyonu Yaşamsal Analizi*. TÜBİTAK, Project report, No 111T681, 45 pp.
- Gücü A.C., Ok, M., Sakinan S., Saydam G., Akkuş G., Kurmuş N., 2015. Mapping the habitats of the critically endangered Mediterranean monk seal (*Monachus monachus*) in the Northeastern Mediterranean. TÜBİTAK, Project report, No 114Z573, 70 pp.
- Google Earth V 7.3.2.5491, 2018. <https://www.google.com/earth/index.html> (Accessed February 2019).
- Harding, K.G., McNamara, J.M., 2002. A unifying framework for metapopulation dynamics. *The American Naturalist*, 160 (2), 173-185.
- Hiby, A.R., Jeffery, J.S., 1987. Census techniques for small populations, with special reference to the Mediterranean monk seal. 193-210. In: *Symposium of the Zoological Society of London, London, 8<sup>th</sup> April-9<sup>th</sup> April 1987*, Oxford: Clarendon Press
- Hiby, L., Paterson, W.D., Redman, P., Watkins, J., Twiss, S.D. *et al.*, 2013. Analysis of photo-id data allowing for missed matches and individuals identified from opposite sides. *Methods in Ecology and Evolution*, 4 (3), 252-259.
- Holt, R.D., Keitt, T.H., Lewis, M.A., Maurer, B.A., Taper, M.L., 2005. Theoretical models of species' borders: single

- species approaches. *Oikos*, 108 (1), 18-27.
- IUCN/UNEP, 1998. *The Mediterranean monk seal*. IUCN, Gland, Switzerland, 59p.
- Jolly, G.M., 1965. Explicit estimates from capture-recapture data with both death and immigration - stochastic model. *Biometrika*, 52, 225-247.
- Karamanlidis, A., Dendrinis, P., 2015. *Monachus monachus*. The IUCN Red List of Threatened Species 2015. 25 pp.
- Karamanlidis, A., Dendrinis, P., De Larrinoa, P.F., Gücü, A. C., Johnson, W.M. *et al.*, 2016. The Mediterranean monk seal *Monachus monachus*: status, biology, threats, and conservation priorities. *Mammal Review*, 46 (2), 92-105.
- Lancia, R.A., Nichols, J.D., Pollock, K.H., 1994. Estimating the number of animals in wildlife populations. p. 215-253 In: *Research and management techniques for wildlife and habitats*. Bookhout, T.A., (Eds). The Wildlife Society, Bethesda, MD.
- Lavigne, D.M., Johnson, W.M., 2001. Hanging by a thread. *BBC Wildlife*, 19 (8), 54-60.
- Marchessaux, D., Muller, N., 1989. *Le phoque moine, Monachus monachus: distribution, statut et biologie sur la cote saharienne*. Port Cros National Park (France), Scientific Reports of the Port Cros National Park, No 13, 60 pp.
- Marcou, M., 2015. *The Mediterranean monk seal Monachus monachus in Cyprus*. (Accessed 7 February 2019) <https://monachus-guardian.org/wordpress/2015/05/21/the-mediterranean-monk-seal-monachus-monachus-in-cyprus/>
- Martínez-Jauregui, M., Tavecchia, G., Cedenilla, M.A., Coulson, T., Fernández de Larrinoa, P. *et al.*, 2012. Population resilience of the Mediterranean monk seal *Monachus monachus* at Cabo Blanco peninsula. *Marine Ecology Progress Series* 461, 273-281.
- Mo, G., Güçlüsoy, H., Savaş, Y., Sigismondi, C., 2001. Pilot study on the use of infrared-sensitive video cameras for the continuous monitoring of caves used by Mediterranean monk seals, *Monachus monachus*. *Mammalia*, 65 (3), 383-386.
- Mo, G., Gazo, M., Ibrahim, A., Ammar, I., Ghanem, W., 2003. Monk seal presence and habitat assessment: results of a preliminary mission carried out in Syria. *The Monachus Guardian*, 6 (1), 1-7.
- Notarbartolo di Sciara, G., Kotomatas S., 2016. Are Mediterranean Monk Seals, *Monachus monachus*, Being Left to Save Themselves from Extinction? *Advances in Marine Biology* 75, 359-386.
- Ok, M., 2006. *Past, Present Status and Future of The Mediterranean Monk Seal (Monachus monachus, Hermann 1779) in The Northeastern Mediterranean*. M.Sc. Thesis, METU Institute of Marine Sciences, Mersin-Turkey, 114p.
- Ok, M., Sakinan, S., Gücü, A. C., 2019. A story of how a critical habitat of an endangered species is lost: the Mediterranean monk seal in the Northeastern (NE) Mediterranean, In: *World Marine Mammal Conference* 19, Dec 2019, Barcelona.
- OSPAR, 2016. *Common Indicator: Seal abundance and distribution (M3)*. <https://www.ospar.org/documents?v=38980> (Accessed 5 April 2020).
- Pastor, T., Aguilar, A., 2003. Reproductive cycle of the female Mediterranean monk seal in the Western Sahara. *Marine Mammal Science*, 19 (2), 318-330.
- Reijnders, P.J.H., Ries, E.H., 1989. *Release and radiotracking of two rehabilitated monk seals in the marine park "Northern Sporades"*, Greece. A report on research conducted by the Research Institute for Nature Management. Texel. 17pp.
- R Core Team, 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org/>.
- Roditi-Elasar, M., Bundone, L., Goffman, O., Scheinin, A.P., Kerem, D.H., 2020. Mediterranean monk seal (*Monachus monachus*) sightings in Israel 2009–2020: Extralimital records or signs of population expansion? *Marine Mammal Science*, 37 (1), 344-351.
- Samaranch, R., González, L.M., 2000. Changes in morphology with age in Mediterranean monk seals (*Monachus monachus*). *Marine Mammal Science*, 16 (1), 141-157.
- Seber, G. A. F., 1965 A note on the multiple recapture census. *Biometrika*, 52(1/2), 249-259.
- Scheinin, A. P., Goffman, O., Elasar, M., Perelberg, A., Kerem, D. H., 2011. Mediterranean monk seal (*Monachus monachus*) resighted along the Israeli coastline after more than half a century. *Aquatic Mammals*, 37 (3), 241.
- Scoullou, M., Mantzara, M., Constantinos, V., 1994. *The Book-Directory for the Mediterranean Monk Seal (Monachus monachus) in Greece*. Elliniki Etairia, 1994, Greece, 167pp.
- Stacey, P.B., Taper, M., 1992. Environmental variation and the persistence of small populations. *Ecological Applications*, 2 (1), 18-29.