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# Using 'pup multipliers' to estimate demographic parameters of Mediterranean monk seals in the eastern Mediterranean Sea

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ABSTRACT: A thorough understanding of population demographics is important in planning and evaluating conservation actions. At the same time, it is also essential that conservation management strives to minimize uncertainty in decision making in order to avoid management errors, which in the case of endangered species might affect their persistence. Mediterranean monk seals are endangered and have been notoriously difficult to count, especially in the eastern Mediterranean Sea, where abundance estimates have relied mainly on expert judgement. To address this problem, a new approach to estimating the species' demographics using 'pup multipliers' is introduced. Adopting a conservative and a more optimistic approach and following a review of the available species- and taxa-specific data, the following multipliers were proposed: 2.5–3.5 for estimating the number of mature individuals, and 4.5–6.0 for estimating the total number of individuals. These multipliers were then used to calculate, in a formal way, the population demographics of the Mediterranean monk seal in the eastern Mediterranean Sea and globally. In their current form, the pup multipliers proposed present a number of strengths, but also several caveats, limitations and/or points of concern and should therefore not be considered a panacea in the conservation of the species, but merely the starting point of efforts for further development. These efforts should ultimately aim at developing a population-specific pup multiplier for the Mediterranean monk seal that is based on a common monitoring approach between various countries and includes the collection of newborn pup count data from across the species' range in the eastern Mediterranean Sea.

KEY WORDS: *Monachus monachus* · Pinnipeds · Conservation · Endangered species · Population estimates · Total abundance

## 1. INTRODUCTION

Thoroughly understanding population demographics is of utmost importance in planning (Chapron et al. 2003) and evaluating conservation actions (Demerdzhiev et al. 2015). At the same time, it is also essential that conservation management strives to minimize uncertainty in decision making (Regan et al. 2005, Horswill et al. preprint doi:10.1101/2021.07.01.450685) in order to avoid, as much as possible, management errors, which in the case of endangered species might affect their persistence (Ceriani et al. 2021). Among the numerous demographic parameters monitored in wildlife populations that are of special importance to conservationists and stakeholders are the number of mature individuals (Mace et al. 2008) and the total population size (Morgan 1999), as they are directly associated with species persistence.

Assessing the number of mature individuals and the total population size has been an integral and important part of the management and conservation of seals (Pinnipedia). Various methodologies have been used to estimate these basic demographic parameters, in-

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cluding, for example, counts of hauled-out animals (Brasseur et al. 2015) and photoidentification and tagging (Forcada & Robinson 2006). However, thoroughly understanding population demography and how it is affected by numerous biological parameters based on such methodologies is not always straightforward, because seals spend considerable time at sea (i.e. out of sight or reach), where they might not be counted. To address this difficulty, conservationists have often estimated total abundance and pup production, in both otariids and phocids (Duck & Thompson 2007, Chilvers 2021) and then used these parameters to define 'pup multipliers' (i.e. ratio of total population numbers to the number of pups; Russell et al. 2019). Harwood & Prime (1978) originally suggested that a ratio between 3.5:1 and 4.5:1 would be appropriate for estimating the total size of increasing populations of most polygynous pinnipeds; however, since then, our understanding of the assumptions and the data behind the development of pup multipliers has improved, and several species-specific multipliers have been developed and used in the management and conservation of seals (see reference list in Table 1).

The Mediterranean monk seal *Monachus monachus* is one of the most endangered seals on Earth and an 'evolutionarily distinct and globally endangered' mammal (Isaac et al. 2007); following a notable recovery in the last 2 decades, the species was listed in 2023 on the Red List of the International Union for Conservation of Nature (IUCN) as Vulnerable (Karamanlidis et al. 2023). Mediterranean monk seals survive currently in 3 subpopulations in the northeastern Atlantic Ocean and the eastern Mediterranean Sea (Karamanlidis 2024). In the Atlantic Ocean, the species has disappeared from most of its original range and survives only along a small stretch of coastline at the Cabo Blanco peninsula (Mauritania/Western Sahara) and in the archipelago of Madeira (Portugal). Systematic, standardized photoidentification studies carried out in the most important pupping and resting sites (i.e. marine caves) in the region have resulted in detailed, reliable demographic data (Karamanlidis 2024). These indicate that both subpopulations are recovering, but also that they suffer from low pup survival rates (Fernández de Larrinoa et al. 2021, Pires et al. 2023); joint analysis of the available photoidentification and telemetry data (Fernández de Larrinoa et al. 2021, Pires et al. 2023) and genetic data (Rey-Iglesia et al. 2021) suggest furthermore that these 2 subpopulations are isolated from each other. Our understanding of the demographic and the overall conservation status of the Mediterranean monk seal in the northeastern Atlantic Ocean is considered good (Karamanlidis 2024).

In the eastern Mediterranean Sea (i.e. mainly in Albania, Greece, Türkiye and Cyprus), systematic monitoring efforts, including photoidentification studies similar to the ones in the Atlantic Ocean, have been carried out throughout the range of the species (e.g. Greece: Bundone & Panou 2022; Türkiye: Gülce et al. 2014; Cyprus: Nicolaou et al. 2019). However, despite these efforts, actual seal numbers in the region remain largely unknown (Panou et al. 2023) and are still based primarily on expert judgement (Karamanlidis et al. 2019). Some of the reasons why photoidentification efforts in the eastern Mediterranean Sea have been less successful than in the Atlantic Ocean include:

- The high number of marine caves potentially available and actually used by Mediterranean monk seals in the region makes systematic photoidentification studies logistically challenging. For example, due to the distinct morphological characteristics of its coastline, Greece alone has >7500 islands and islets (Triantis & Mylonas 2009) and countless marine caves are potentially available to the species. Currently the terrestrial habitat of the Mediterranean monk seal in Greece comprises more than 500 and 100 marine caves that have been documented to have been used for resting and pupping respectively. Similarly, the terrestrial habitat of the Mediterranean monk seal in Albania, Türkiye and Cyprus includes numerous marine caves all along their coastlines (Karamanlidis 2024).
- Some of the most suitable caves for Mediterranean monk seals in the region are not frequented by the species because of increased human pressure (Kıraç & Savaş 2019). In addition, some individuals in the eastern Mediterranean monk seal subpopulation do not use the main pupping and resting caves, which are often prioritized for photoidentification studies, anyway. These individuals may include adult males that use the main pupping and resting caves less frequently during the pupping season or adult females that move out of the main pupping sites in order to reduce intra-specific competition (Karamanlidis 2024). The fact that Mediterranean monk seals have been recently recorded in Greece to rest at sea complicates matters further (Karamanlidis et al. 2017).
- Mediterranean monk seals in the eastern Mediterranean Sea have been showing a notable recovery recently, which has manifested itself in the increase of the extent of the terrestrial habitat used (Panou et al. 2022) and the subsequent increase in the range of the species (Adamantopoulou et al. 2022). During this recovery, seals in the region have been recorded

using also 'suboptimal habitat' (i.e. caves with underwater entrances and/or no resting surface) (Karamanlidis 2024), which are difficult to monitor, or open beaches (Dendrinos et al. 2022), which are difficult to identify because of their high number (i.e. Greece has >16 000 km of coastline with countless open beaches).

• Mediterranean monk seals in the eastern Mediterranean Sea move extensively between the coastal waters of several countries (Karamanlidis 2024), which may result in double counting, if monitoring efforts are not coordinated.

Taking into account these limitations, it is easy to understand why estimating the demographic parameters for the Mediterranean monk seal subpopulation in the eastern Mediterranean Sea or even on a national level is considered an extremely difficult (and inexact) task (Kurt & Gücü 2021, Pietroluongo et al. 2022). Because of the general lack of detailed demographic data, our understanding of the conservation status of the Mediterranean monk seal subpopulation in the eastern Mediterranean Sea is considered less detailed than that of the subpopulations in the Atlantic Ocean (Karamanlidis 2024), which in turn might impede the development of coherent conservation and management strategies for the species in the region (Baylis et al. 2019). Considering furthermore that the aforementioned limitations of photo-identification studies in the eastern Mediterranean Sea are not likely to be overcome soon, the development of an alternative way to estimate the basic demographic parameters for the Mediterranean monk seal in the eastern Mediterranean Sea would be beneficial for the overall management and conservation of the species.

The aims of the study were (1) to propose pup multipliers for the Mediterranean monk seal that could be used to estimate the number of mature (termed 'mature multiplier') and the total number of individuals in a given management unit (termed 'total population multiplier') in the eastern Mediterranean Sea, and (2) use these multipliers to estimate in a formal way the basic demographic parameters of the eastern Mediterranean subpopulation and the global population of the Mediterranean monk seal.

## 2. METHODS

Pup multipliers for the Mediterranean monk seal in the eastern Mediterranean were proposed following (1) a review of relevant information and the inference of the respective multipliers based on data from the Mediterranean monk seal subpopulations in the Cabo Blanco and the archipelago of Madeira, and select reproductive nuclei in Greece for which relevant data were available (i.e. at the islet of Astakida and the island of Gyaros in the Aegean Sea); and (2) a thorough review of the scientific literature in order to identify, infer and/or summarize pup multipliers used in the monitoring, management and conservation of other seal species.

Taking into account the overall limited understanding of the species' demographics in the eastern Mediterranean Sea and in order to address as many demographic scenarios and population trajectories as possible (i.e. from decreasing to increasing populations), 2 multipliers were arbitrarily proposed for each demographic parameter: 1 multiplier following a conservative approach that should be considered the minimum estimate, and 1 multiplier following a more optimistic approach that should be considered the maximum estimate of each demographic parameter respectively.

The proposed pup multipliers were then used in the calculation of the number of mature and the total number of Mediterranean monk seals in the range countries of the species in the eastern Mediterranean Sea and globally. When calculating the demographics of Mediterranean monk seals in the eastern Mediterranean Sea, the IUCN Criteria were applied (IUCN Standards and Petitions Committee 2022), and a remainder population was added to include all the individuals that are currently not covered by systematic monitoring efforts. It should be noted that because of irregular pupping, Albania has been included in this group. The demographic parameters of this remainder population were determined also arbitrarily following a conservative approach.

## 3. RESULTS

The results of the review of the scientific literature and of the inferences of pup multipliers to estimate the number of mature and the total number of Mediterranean monk seals in the eastern Mediterranean Sea are presented in Table 1.

Mature multipliers ranged between 2.00 and 3.71 in select subpopulations and reproductive nuclei of the Mediterranean monk seal and between 1.45 and 3.53 in phocids and otariids. Total population multipliers ranged between 3.00 and 7.71 in select subpopulations and reproductive nuclei of the Mediterranean monk seal, and between 3.50 and 6.75 and between 3.16 and 5.59 in phocids and otariids, respectively

Table 1. Pup multipliers for various pinniped species and some of their subpopulations/reproductive nuclei. $N_{mature}$: number of mature individuals; $N_{total}$: total number of individuals; $N_{pup}$: mean number of pups born annually

| Species | $N_{mature}$ | $N_{total}$ | $N_{pup}$ | Mature multiplier | Total population multiplier | Reference |
|---|---|---|---|---|---|---|
| **Phocidae** | | | | | | |
| Mediterranean monk seal *Monachus monachus* | | | | | | |
| Archipelago of Madeira | 13 | 27 | 3.5 | 3.71 | 7.71 | Pires et al. (2023); R. Pires (pers. comm.) and Instituto das Florestas e Conservação da Natureza (IFCN) (unpubl. data) in Karamanlidis et al. (2023) |
| Cabo Blanco | 184 | 350 | 70 | 2.63 | 5.00 | Fernández de Larrinoa et al. (2021); Fernandez de Larrinoa (pers. comm.) and CBD Habitat (unpubl. data) in Karamanlidis et al. (2023) |
| Astakida | 12 | 18 | 6 | 2.00 | 3.00 | MOm (2008)[a] |
| Gyaros | 18 | | 8 | 2.25 | | Karamanlidis & Dendrinos (2012)[a] |
| Baikal seal *Pusa sibirica* | | 131800 | 23600 | | 5.58 | Goodman (2016) |
| Grey seal *Halichoerus grypus* | | | | | 3.50–5.40 | Hewer (1964), Mansfield & Beck (1977), Stobo & Zwanenburg (1990), Haug et al. (1994), Hammill et al. (1998), Hauksson (2007), Nilssen & Haug (2007) |
| Harp seal *Pagophilus groenlandicus* | | 6800000 | 1039000 | | 6.54 | Hammill et al. (2021) |
| Hawaiian monk seal *Neomonachus schauinslandi* | 632 | 1209 | 179 | 3.53 | 6.75 | Littnan et al. (2015), J. Baker (pers. comm.) in Karamanlidis et al. (2023) |
| **Otaridae** | | | | | | |
| Antarctic fur seal *Arctocephalus gazella* | | | | | 4.10 | Payne (1979), Page et al. (2003) |
| Australian fur seal *A. pusillus doriferus* | | | | | 3.95–4.50 | Goldsworthy et al. (2003), Kirkwood et al. (2005, 2010), Gibbens & Arnould (2009) |
| Australian sea lion *Neophoca cinerea* | | | | | 3.8–4.8 | Gales et al. (1994), Goldsworthy & Page (2007), Goldsworthy et al. (2010) |
| California sea lion *Zalophus californianus* | | | | | 4.32–5.59 | Carretta et al. (2016), Laake et al. (2018) |
| Guadalupe fur seal *A. townsendi* | | | | | 4.5 | Hernández-Camacho & Trites (2018) |
| New Zealand fur seal *A. forsteri* | | | | | 4.76–4.90 | Taylor (1982), Shaughnessy et al. (1997), Goldsworthy & Page (2007), Chilvers (2021) |
| New Zealand sea lion *Phocarctos hookeri* | 3031 | | 2084 | 1.45 | 4.40–5.08 | Gales & Fletcher (1999), Chilvers (2015), Chilvers & Meyer (2017), Hamilton & Baker (2019) |
| Northern elephant seal *Mirounga angustirostris* | | | | | 4.40 | Lowry et al. (2014) |
| Northern fur seal *Callorhinus ursinus* | | | | | 4.47 | Muto et al. (2022) |
| South African fur seal *A. pusillus pusillus* | | | | | 4.77–5.40 | Butterworth et al. (1988), Butterworth & Wickens (1990), Wickens & Shelton (1992) |
| South American fur seal *A. australis* | | | | | 3.16–4.97 | Baylis et al. (2019) |
| Steller sea lion *Eumetopias jubatus* | | | | | 4.20–5.20 | Calkins & Pitcher (1982), Trites & Larkin (1996), Pitcher et al. (2007) |

[a]Unpublished reports. See footnotes 1 & 2 in text

(Table 1). Based on these results, the following pup multipliers were arbitrarily proposed:

- Mature multipliers recorded for the Mediterranean monk seal were similar to mature multipliers inferred in 2 other seal species, i.e. the closest relative of the Mediterranean monk seal, the Hawaiian monk seal and the New Zealand sea lion, that have population trajectories that are very similar to that of the Mediterranean monk seal (Chilvers 2015, Littnan et al. 2015). We consider the mature multipliers inferred for the reproductive nuclei in Astakida and Gyaros in Greece and in the subpopulation in the archipelago of Madeira not to be representative of the situation throughout the eastern Mediterranean Sea. The multipliers in the reproductive nuclei in Astakida and Gyaros, according to unpublished reports by MOm[1] and Karamanlidis & Dendrinos[2], respectively, are likely underestimates, because a part of the popula-

Table 2. Estimates of mature individuals and total population size of Mediterranean monk seals in the eastern Mediterranean Sea using the proposed pup multipliers. A: minimum estimate of total N of mature individuals; B: maximum estimate of total N of mature individuals; C: minimum estimate of total N of individuals; D: maximum estimate of total N of individuals

| Country | $N_{pup}$ | A | B | C | D | Data source of $N_{pup}$ |
|---|---|---|---|---|---|---|
| Greece | 75 | 187 | 262 | 337 | 450 | Karamanlidis & Dendrinos (2023); MOm (unpubl. data) in Karamanlidis et al. (2023) |
| Türkiye | 17 | 42 | 59 | 76 | 102 | M. Ok & C. O. Kiraç (pers. comm.) and SAD-AFAG (unpubl. data) in Karamanlidis et al. (2023) |
| Cyprus | 3 | 7 | 10 | 13 | 18 | H. Nicolaou (pers. comm.); Department of Fisheries and Marine Research Cyprus (unpubl. data) in Karamanlidis et al. (2023) |
| Remainder | 2 | 10 | 10 | 12 | 12 | Present study |
| Total | 97 | 246 | 341 | 438 | 582 | |

Table 3. Global estimates of mature individuals and population size of the Mediterranean monk seal using the proposed pup multipliers. A: minimum estimate of total N of mature individuals; B: maximum estimate of total N of mature individuals; C: minimum estimate of total N of individuals; D: maximum estimate of total N of individuals

| Subpopulation | $N_{pup}$ | A | B | C | D | Data source |
|---|---|---|---|---|---|---|
| Madeira | 3.5 | 13 | 13 | 27 | 27 | Pires et al. (2023); R. Pires (pers. comm.) and IFCN (unpubl. data) in Karamanlidis et al. (2023) |
| Cabo Blanco | 70 | 184 | 184 | 350 | 350 | Fernández de Larrinoa et al. (2021); Fernández de Larrinoa (pers. comm.) and CBD Habitat (unpubl. data) in Karamanlidis et al. (2023) |
| Eastern Mediterranean | 97 | 246 | 341 | 438 | 582 | Present study |
| Total | 170.5 | 443 | 538 | 815 | 959 | |

tion (i.e. adult males) did not frequent the reproductive caves monitored, whereas the multiplier in the subpopulation in the archipelago of Madeira is likely an overestimate that is related to the current demographic situation of the species in the region (i.e. very low pup survival, very low reproductive rates; Pires et al. 2023). The mature multiplier inferred for the recovering Mediterranean monk seal subpopulation in Cabo Blanco (which has the most robust dataset) is the one most likely to reflect the actual situation throughout the eastern Mediterranean Sea. Considering the previous, a conservative mature multiplier of 2.5 is proposed, which is even lower than the one calculated for the subpopulation in Cabo Blanco (i.e. 2.63); the more optimistic mature multiplier is set at 3.5.

• Total population multipliers recorded for the Mediterranean monk seal were similar to the multipliers recorded in other pinnipeds, with the exception of the multiplier for the archipelago of Madeira. As in the case of the mature multiplier, the total population multiplier inferred for the archipelago of Madeira is likely an outlier, and the respective multiplier for the subpopulation in Cabo Blanco should be considered the one that most likely reflects the current demographic situation in the eastern Mediterranean Sea. Considering the previous, a conservative total population multiplier of 4.5 is proposed, which is even lower than the one inferred for the Mediterranean monk seal subpopulation in Cabo Blanco (i.e. 5.0); the more optimistic total population multiplier is set at 6.0.

Using the multipliers proposed in the previous step (i.e. mature multiplier: 2.5–3.5; total population multiplier: 4.5–6.0), the basic demographic parameters of the Mediterranean monk seal subpopulation in the eastern Mediterranean and in the global population of the species were calculated. These calculations resulted in a total estimate of 438–582 (including 246–341 mature individuals) (Table 2) and 815–959

[1]MOm (2008) Unpublished final report on the monitoring of the status of the population of the monk seal, in Karpathos and Saria. MOm/Hellenic Society for the Study and Protection of the Monk Seal, Athens

[2]Karamanlidis AA, Dendrinos D (2012) A glimpse into the past, a prospect for the future: studying the status and behavior and promoting conservation of Mediterranean monk seals at the island of Gyaros. Unpublished final report to the National Geographic Grant #W178-11. MOm/Hellenic Society for the Study and Protection of the Monk Seal, Athens

(including 443–538 mature individuals) (Table 3) for the eastern Mediterranean and the global population of the Mediterranean monk seal respectively.

## 4. DISCUSSION

Mediterranean monk seals have been recently making a notable recovery that has created a new conservation reality for the species (Karamanlidis 2024), which requires reliable demographic data in order to plan and evaluate management and conservation actions. The present study introduces a new approach to estimating basic demographic parameters of the Mediterranean monk seal in the eastern Mediterranean Sea using arbitrarily proposed pup multipliers.

The pup multipliers have been proposed considering data from other subpopulations of the species, but also data from other pinnipeds. Considering data from other seal species has been necessary, especially in cases, such as in the Mediterranean monk seal, where detailed demographic data are missing (e.g. Trites & Larkin 1996, Lowry et al. 2014, Punt et al. 2020). While caution is generally needed when using multipliers that are not species-specific (Frie et al. 2012), in the case of the Mediterranean monk seal it is not unreasonable to consider multipliers from other species and/or taxa, even from otariids, since Mediterranean monk seals exhibit a maternal care system and population structure that lies between the phocid and otariid patterns, perhaps being closer to the latter (Pastor et al. 2011).

While proposing these Mediterranean monk seal-specific pup multipliers, it is acknowledged that, in their present form, they have certain caveats, limitations and/or points of concern, including:

- Extrapolating from pups to total population and creating pup multipliers requires the calculation of life tables (Pitcher et al. 2007, Lowry et al. 2014) that need detailed information on demographic parameters (e.g. age-specific survival and fecundity rates) that should be representative of the population to which the pup counts are being extrapolated (Russell et al. 2019). Such information is not available yet for the Mediterranean monk seal in the eastern Mediterranean Sea.
- Pup counts can be good indicators of abundance in populations with stable age distributions. If age distributions are shifting due to ecosystem changes or other factors, pup counts will not be a good indicator until the population reaches a new stable age distribution (Berkson & DeMaster 1985). In the case of the Mediterranean monk seal in the eastern Mediterranean Sea, too little information is available on the age distribution in order to evaluate if and how the proposed pup multipliers might be affected. Unstable age distribution might have been an issue for the Mediterranean monk seal subpopulation in Cabo Blanco during the mass die-off in 1997, when a rapid change (i.e. within a couple of months almost two-thirds of the adult population died) in demographic parameters took place. However, as this subpopulation has now recovered to its pre mass die-off levels (Fernández de Larrinoa et al. 2021), there is little reason to suspect such an effect in this subpopulation. We speculate that the same applies to the subpopulation in the eastern Mediterranean, but extensive research is still necessary in order to verify this assumption.
- Changes in population demography and exchanges with other populations nearby might affect the number of animals present in a way which is not deducible from pup counts alone (Härkönen & Harding 2001). While this is not a major issue in the isolated Mediterranean monk seal subpopulations in the archipelago of Madeira and Cabo Blanco, it should be considered a problem in the eastern Mediterranean, where evidence from genetic (Karamanlidis et al. 2021b) and photoidentification efforts indicates that mature Mediterranean monk seals move extensively throughout the region (Karamanlidis 2024).

On the other hand, counting pups and using pup multipliers as an approach to estimate basic demographic parameters of Mediterranean monk seals in the eastern Mediterranean Sea also has several strengths, including:

- Newborn pups (i.e. pups until approximately the age of 2 mo that have not undergone the first molt) are the easiest age class in Mediterranean monk seals to count: newborn pups spend the most time of all age classes on land (Karamanlidis et al. 2021a), at the easiest-to-predict locations (i.e. pupping caves; Dendrinos et al. 2007) and are among the easiest to identify because of their unique, external appearance (i.e. sexually dimorphic patch on the ventral side; Samaranch & González 2000). All these facts, in combination with the limited mobility of newborn pups, reduce significantly the possibilities of double-counting individuals in geographically overlapping population nuclei, while reducing at the same time monitoring and logistic efforts.
- In contrast to photoidentification studies aiming at monitoring the adult segment of a population that need to be carried out year-round in order to be accurate, counting newborn pups in the eastern Mediterranean can focus on the pupping season, which

extends mainly during the months September—December (Karamanlidis 2024), thus, reducing considerably monitoring and logistic efforts.

• When using pup multipliers, one should always keep in mind that the maximum number of pups counted during a survey is always an underestimate of the total annual pup production. At the time of a survey, some pups are yet to be born, while others are not counted, as they may have already left the colony, or died (Boveng et al. 1998). In the case of the Mediterranean monk seal, monitoring efforts throughout the range of the species have tried to minimize this error in order to obtain an unbiased estimate of total pup production, by carrying out multiple field surveys to the main pupping sites throughout the entire pupping season, combined with the deployment of camera traps and photoidentification techniques (for similar adaptations in monitoring techniques, see Russell et al. 2019). Compared to other pinnipeds, the number of newborn Mediterranean monk seal pups going undetected in closely monitored populations should be considered small.

Considering the caveats, limitations and/or points of concern, but also their strengths, the proposed pup multipliers should not be considered, in their present form, a panacea for Mediterranean monk seal management and conservation, but merely a starting point for further research and improvement.

In contrast to the archipelago of Madeira (Pires et al. 2023) and Cabo Blanco (Forcada & Aguilar 2000, Martínez-Jauregui et al. 2012, Fernández de Larrinoa et al. 2021), Mediterranean monk seals in the eastern Mediterranean Sea have been notoriously difficult to count. Population estimates in the region have been based primarily on expert judgement (Karamanlidis et al. 2019) that relied on data of questionable quality, which has led previously to false predictions of the species' trajectory (Goedicke 1981). The development of pup multipliers for the Mediterranean monk seal subpopulation in the eastern Mediterranean Sea, although necessary to be treated with caution, is the first step in estimating in a formal way Mediterranean monk seal population demographics in the region.

The demographic parameters calculated in the present study show some notable differences from the demographic parameters currently associated with the species. More specifically, the number of mature individuals estimated in the eastern Mediterranean Sea (i.e. 246—341) is slightly higher than the number of mature individuals estimated during the last assessment of the conservation status of the eastern Mediterranean subpopulation of the species by the IUCN (i.e. 187—240; Karamanlidis et al. 2019). It is also slightly higher than the cut-off value of 250 mature individuals of criterion D (IUCN Standards and Petitions Committee 2022), by which the Mediterranean monk seal subpopulation in the region was listed as Endangered. This fact might warrant a reassessment of the conservation status of the Mediterranean monk seal subpopulation in the eastern Mediterranean Sea. Similarly, the global estimate of mature individuals of the present study (i.e. 443—538) is higher than the number of mature individuals estimated during the previous global assessment of the Mediterranean monk seal by the IUCN (i.e. 350—450; Karamanlidis & Dendrinos 2015). Furthermore, the demographic parameters of the study for Türkiye differ from the ones used to evaluate the species in the current global assessment (Karamanlidis et al. 2023); the reason for this is that population demographics for the species in Türkiye in the current global IUCN species assessment are based on a combination of expert judgement and the use of the pup multipliers (Karamanlidis 2024), which slightly increased estimates. Finally, the global abundance estimate of the study is considerably higher than the total population estimate often associated with the species currently (i.e. 600—700 individuals; e.g. Pietroluongo et al. 2022, Panou et al. 2023). Even by this new estimate, with a global population of < 1000 individuals, the Mediterranean monk seal should be considered, by population size standards, the most endangered seal species on Earth.

## 5. CONCLUSIONS

Quantifying trends in the abundance of animal populations is a central tenet in ecology that underpins animal management and conservation (Caughley & Gunn 1996). The conservation and management implications of the present study are profound: the pup multipliers proposed in the study provide for the first time a formal way to estimate basic demographic parameters of Mediterranean monk seals in the eastern Mediterranean Sea. The use of the study's multipliers is understandably very general, particularly considering that multipliers vary according to (sub)population growth rate (Lalas & Bradshaw 2001), and the fact that the proposed multipliers have been proposed based on data from other seals and other Mediterranean monk seal subpopulations. They should be considered therefore merely a starting point of efforts for further improving this monitoring approach. These efforts should include a formal assessment of the accuracy of the proposed multipliers using demographic data from the Cabo Blanco Mediterranean monk seal subpopulation (Lowry et al. 2014), while collecting at the same time the necessary population-specific data. The efforts should ultimately aim at establishing a robust (i.e. standardized) monitoring approach that includes coordination between various research groups and countries and the collection of newborn pup count data across the species' range in the eastern Mediterranean Sea (Pitcher et al. 2007).

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