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Diet of a Mediterranean monk seal *Monachus monachus* in a transitional post-weaning phase and its implications for the conservation of the species

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ABSTRACT: The Mediterranean monk seal *Monachus monachus* is the most endangered pinniped in the world and is considered Endangered by the IUCN. Transition from suckling to active feeding is a critical time in the development of all mammal species, and understanding the dietary requirements of seals during this vulnerable period is of value in establishing conservation measures, such as fishery regulations. This study provides unique information on the dietary habits of a moulted monk seal pup, through the opportunistic necropsy of a dead animal encountered at a very early age (5 mo). A total of 6 prey items from 2 families (Octopodidae, 90.8% and Congridae, 8.9%) were identified from stomach contents. The remaining stomach content mass consisted of fish bones from unidentified species (0.3%). The estimated age, low diversity and number of prey items in the stomach contents indicate that this individual may have been in a transition period from suckling to active feeding. The study confirms independent foraging in Mediterranean monk seals at about 5 mo of age. Given the importance of early life survival for maintaining stable Mediterranean monk seal populations, and the occurrence of an ontogenetic shift in its close relative (Hawaiian monk seal), these findings contribute to the establishment and implementation of successful conservation and management strategies for this Endangered species.

KEY WORDS: Mediterranean monk seal · *Monachus monachus* · Diet · Stomach content · Early life stage · Conservation · Eastern Mediterranean

1. INTRODUCTION

The Mediterranean monk seal *Monachus monachus* (Hermann 1779), a living relic of the Mediterranean Sea, is the only surviving representative of the genus *Monachus* (Scheel et al. 2014). With only 600–700 individuals estimated worldwide (both Atlantic and Mediterranean populations), the current status of the species is Endangered (EN) based on the recent global assessment by the IUCN (Karamanlidis & Dendrinis 2015). The Mediterranean subpopulation is considered Critically Endan-

gered (Aguilar & Lowry 2010) and is restricted to the eastern Mediterranean basin, with 300–400 in Greece (Karamanlidis & Dendrinis 2015) and minimum 100 in Turkey (Güçlüsoy et al. 2004), including 35 seals on the south coast of Turkey, with an additional 5 seals identified in Northern Cyprus (Gucu et al. 2009). Monk seals are also repeatedly observed in, for example, Albania, Croatia, Italy and Lebanon (di Sciara et al. 2019). Throughout its global distribution range (which, outside the Mediterranean, includes a population on the west coast of Africa in Mauritania), Turkish coasts are among

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the last strongholds of this elusive and very rare marine mammal (Karamanlidis et al. 2016).

Foraging behaviour and dietary preferences are among the least known subjects related to the biology of this species (Karamanlidis et al. 2011, Pierce et al. 2011). Studies on the dietary habits of the Mediterranean monk seal are very limited (Cebrian et al. 1990, Karamanlidis et al. 2011, 2014, Pierce et al. 2011), and there are only 2 studies of the diet of this species in Turkish waters. Salman et al. (2001) examined the diet of juvenile and sub-adult female monk seals from the Aegean coast and outlined the importance of cephalopods in their diet. The second study, 15 yr later, examined the stomach of an adult female found dead in Antalya, a large city located along the Mediterranean coast of Turkey (Tonay et al. 2016).

The current study reports on the diet analysis of a moulted monk seal pup found dead at sea. Our aim was to provide baseline dietary and feeding behaviour information for the early and underrepresented life stage during the transitional phase from suckling to active feeding.

2. MATERIALS AND METHODS

The seal carcass was found at sea on 26 March 2017 by an artisanal fisherman within the Foça Special Environment Protected Area (SEPA since 1991), approximately 450 m offshore from the coast of Foça (İzmir, Turkey, Aegean Sea) (Fig. 1). A team member from Underwater Research Society-Mediterranean Seal Research Group (SAD-AFAG), the national non-governmental organization (NGO) dedicated to conservation of the Mediterranean monk seal in Turkey, arrived in Foça on the same day, after an alert by the abovementioned fisherman through the national Monk Seal Information and Rescue Network (AFBIKA). A necropsy was performed on the same day of carcass discovery following the protocols outlined by Rowles et al. (2001).

The entire stomach and intestine were removed for the analysis. The intestine contents were also carefully removed and analysed for the presence of any

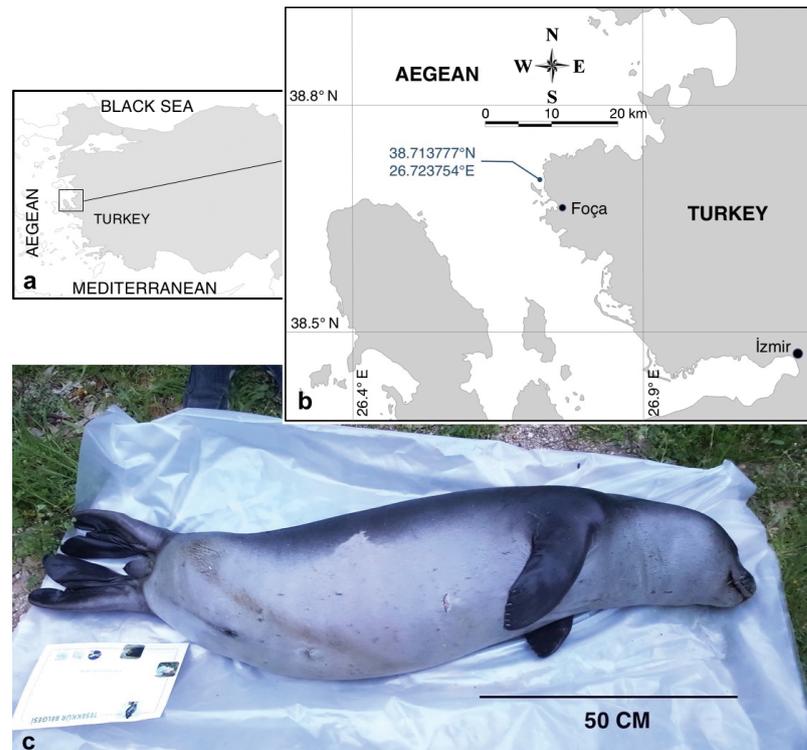


Fig. 1. (a) General and (b) specific location of the (c) moulted Mediterranean monk seal pup carcass discovered off the coast of Turkey on 26 March 2017. Photo: C.O.K., SAD-AFAG

food items. All prey items recovered from the stomach were photographed. They were then separated into intact and fragmented items and wet-weighted to the nearest 1g with a digital scale before being transferred to separate containers filled with 10% formalin for further laboratory analysis. Then, in the laboratory, the contents were washed through a 100 µm sieve.

The taxonomic identification of fish, cephalopods and beak remains was carried out according to Bauchot & Saldanha (1986), Jereb et al. (2010) and Clarke (1986). The dental formulae of the conger and cephalopod beaks were examined for taxonomic identification purposes under a stereomicroscope up to 40× magnification.

3. RESULTS

The carcass decomposition code was determined as 2, which refers to a freshly dead 'edible' marine mammal, according to Rowles et al. (2001).

Based on external appearance and standard measurements obtained during the necropsy (total body length: 153 cm; weight: 48.77 kg; blubber thickness

at the belly: ca. 50 mm; penis bone: ca. 50 mm), and this individual was identified as a Class A (youngster) based on morphological categories determined by Samaranch & González (2000) and is a moulted male pup of about 5 mo, hereafter referred to as a moulted monk seal pup. The Mediterranean monk seal pupping season lasts from June–December (Gucu et al. 2004) with a peak in October (Sergeant et al. 1979), indicating this seal was likely born during the previous 2016 breeding season.

The stomach was more than half-full and the total contents weighed 0.371 kg (0.76% of total body weight). In total, prey representing 6 items of 2 species were identified in the stomach contents (Table 1, Fig. S1 in the Supplement at www.int-res.com/articles/suppl/n039p315_supp.pdf). The prey species were teleost fish (n = 1) and cephalopods (n = 5) belonging to the families Congridae and Octopodidae respectively. The single fish species was identified as a bandtooth conger eel *Ariosoma balearicum*; this specimen was intact and was weighed individually. All 5 octopus prey items were identified as the common octopus *Octopus vulgaris*. Of these, 2 individuals (items #1 and #2) were intact, showing only initial signs of digestion. These 2 whole octopus prey items were individually weighed. The remaining fragmented octopus sample was weighed as a group (item #3), in which 2 octopuses were identified by preserved fleshy head parts and beak pairs, while the remaining octopus was almost digested and identified only by a beak pair. Finally, hard remains (mainly fish vertebral columns) were separated and weighed as trace items (Table 1). These could not be identified. No separate otoliths were found either inside the stomach or in the intestines. In addition, there were no signs of milk presence in the stomach or intestines, and the intestines contained no dietary items.

4. DISCUSSION

The seal investigated in this study is the smallest (and therefore the youngest) Mediterranean monk seal to feature in a dietary analysis (Table 2). Physical appearance in general, blubber thickness and total weight indicated that the young monk seal was well-fed and healthy at the time of death. One of the most striking features of this species is the nursing period, which is considered to be the longest of all phocid species (Aguilar et al. 2007). In the early 1980s, Mursaloğlu (1984) reported that the lactation period lasts about 4–4.5 mo; more recently, Aguilar et al. (2007) conservatively estimated that lactation continues for up to 5 mo. Although no milk was detected along the digestive tract, considering the estimated age (about 5 mo old) and stomach contents of the individual examined here and the lactation period of the species reported in the literature, it is likely that this individual was in the transition period from suckling to active feeding. The study thus confirms that at 5 mo old, Mediterranean monk seals can successfully forage and prey on marine organisms.

Of the total number of prey items recovered and identified in the sample, cephalopods represented the largest component, followed by teleosts. Diet items were similar to those found in other dietary studies of the species. These results are in accordance with the current information available for this species in the eastern Mediterranean Sea: members of the Octopodidae family are known to be favourite prey items for the species (Pierce et al. 2011; our Table 2). The bandtooth conger eel *Ariosoma balearicum*, found in the stomach of the seal, was not fully broken, and 2 external and deep incisions in its flesh resembled cuts made by the seal's premolar/molar teeth during capture. The conger specimen had clearly been swallowed whole by the young monk seal. One of the most

Table 1. Prey items collected and identified in the stomach contents of the deceased moulted Mediterranean monk seal pup

Sub-order	Family	Species	n	Wet weight (g)	Mass (%)	Notes
Osteichthyes	Congridae	<i>Ariosoma balearicum</i>	1	33	8.9	Whole
	Sub-total		1	33	8.9	
Cephalopoda	Octopidae	<i>Octopus vulgaris</i> #1	1	88	23.7	Whole
		<i>Octopus vulgaris</i> #2	1	136	36.7	Whole
		<i>Octopus vulgaris</i> #3	3	113 ^a	30.4	Fragmented
	Sub-total		5	337	90.8	
Fish bones ^b			4	1	0.3	Tiny pieces
	Total		10	371	100	

^aIncluding the 3 pairs of beaks that were found inside the fragmented pieces; ^bpieces of vertebral columns

Table 2. Fish and cephalopod species reported in previous studies on the diet of the Mediterranean monk seal in the Mediterranean Sea. TL: total length of the seal(s) investigated; na: not available

Species	Cebrian et al. (1990)	Salman et al. (2001)	Karamanlidis et al. (2011)	Pierce et al. (2011)	Tonay et al. (2016)	This study
	Aegean 1 adult male (TL: 239 cm)	Aegean 1 subadult female (TL: 200 cm) 1 juvenile female (TL: 176 cm)	Aegean 1 subadult male (TL: 180 cm)	Aegean 10 subadult males 7 subadult males 5 adult females (TL: na)	East Med 1 adult male (TL: na)	Aegean 1 moulted pup male (TL: 153 cm)
Osteichthyes						
<i>Boops boops</i>	+			+		
<i>Oblada melanura</i>	+			+		
<i>Diplodus vulgaris</i>	+		+			
<i>Lophius</i> spp.	+			+		
<i>Serranus</i> spp.	+			+		
<i>Scomber scombrus</i>	+					
<i>Mullus</i> spp.	+			+		
Triglidae	+					
<i>Symphodus tinca</i>			+			
<i>Sarpa salpa</i>			+			
<i>Conger conger</i>			+	+		
<i>Dentex</i> spp.					+	
<i>Dentex marrocanus</i>					+	
<i>Pagellus</i> spp.				+	+	
<i>Pagellus erythrinus</i>			+	+	+	
<i>Ariosoma balearicum</i>					+	+
<i>Argyrosomus regius</i>					+	
<i>Scorpaena porcus</i>			+	+		
<i>Scyliorhinus</i> spp.				+		
<i>Muraena helena</i>				+		
<i>Merluccius merluccius</i>				+		
<i>Phycis blennoides</i>				+		
<i>Phycis phycis</i>				+		
<i>Dicentrarchus labrax</i>				+		
<i>Serranis hepatus</i>				+		
<i>Trachurus</i> spp.				+		
<i>Pagrus pagrus</i>				+		
<i>Pagellus acarne</i>				+		
<i>Pagellus bogaraveo</i>				+		
<i>Lithognathus mormyrus</i>				+		
<i>Diplodus</i> spp.				+		
<i>Diplodus annularis</i>				+		
<i>Spondyliosoma cantharus</i>				+		
<i>Spicara</i> spp.				+		
<i>Spicara flexiosa</i>				+		
<i>Spicara maena</i>				+		
<i>Coris julis</i>				+		
<i>Sparisoma cretense</i>				+		
<i>Gobius</i> spp.				+		
<i>Gobius bucchichi</i>				+		
<i>Atherina hepsetus</i>				+		
<i>Scorpaena scrofa</i>				+		
<i>Arnoglossus</i> spp.				+		
<i>Citharus linguatula</i>				+		
<i>Synapturichthys kleinii</i>				+		
Cephalopoda						
<i>Octopus vulgaris</i>			+	+	+	+
<i>Eledone mochata</i>		+		+		
<i>Bathypolypus sponsalis</i>		+				
<i>Sepia officinalis</i>	+	+		+		
<i>Loligo vulgaris</i>			+			
<i>Eledone cirrosa</i>				+		
<i>Loligo</i> spp.				+		
Testudines						
<i>Chelonia mydas</i>					+	

interesting points is that this prey item is a nocturnally active species that stays burrowed in the sand and mud during daytime (Froese & Pauly 2018), implying that the moulted pup may have been actively feeding at night. The ontogenetic shift in diet of the Mediterranean monk seal is unknown, but the Hawaiian monk seal, a close relative of the Mediterranean monk seal, is known to have an ontogenetic shift in diet (Longenecker 2010); juveniles and subadults were found to have a higher proportion of nocturnal than diurnal teleost species in their diet, whilst the reverse pattern was seen in adults (Longenecker 2010). Moreover, regarding the diets of juvenile Hawaiian monk seals, the highest % frequencies of prey occurrence were marine conger eels, including the *Ariosoma* genus (Longenecker 2010). This may also be the case for the Mediterranean monk seal, as *A. balearicum* was previously identified in the stomach contents of a monk seal by Tonay et al. (2016); however, the individual in question was an adult, highlighting that further research is needed on this topic.

Among the prey items found and identified in the stomach contents of the moulted monk seal pup, *Octopus vulgaris* specimens were all identified as juveniles due to their small sizes (weight range: 88–136 g; Cuccu et al. 2013), whilst the *A. balearicum* specimen was an adult individual of 28 cm total length (Froese & Pauly 2018). The presence of juvenile octopuses as prey items may be due to prey size preferences of younger seals, an indication of hunting inexperience or a reflection of the population structure of the prey.

Considering that the Mediterranean monk seal is one of the most endangered and least studied species in the world, knowledge of the biology of the species is especially important for developing robust conservation policies. Transition from suckling to active feeding is a critical time in the life of all mammal species that receive parental care (Carter et al. 2017). This study contributes to a better understanding of the diet and feeding behaviour of the early life stage of the Mediterranean monk seal. Given the importance of early life survival for maintaining stable populations (Ok 2006), this information is a key component towards the establishment of successful conservation and management strategies.

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