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OBSERVATIONS OF A JUVENILE BASKING SHARK *CETORHINUS MAXIMUS* IN THE ADRIATIC SEA SUPPORT THE HYPOTHESIS OF A DISTINCT MEDITERRANEAN POPULATION

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ABSTRACT

The basking shark Cetorhinus maximus is a large planktivorous shark which sightings in the Mediterranean Sea have increased in recent decades, particularly in the Adriatic Sea. This study reports the incidental capture and release of a juvenile basking shark (estimated total length ~2 m) in July 2015 near the island of Mljet, Eastern South Adriatic. The observation aligns with prior records indicating the appearance of juveniles and subadults during summer, after the departure of adults in late spring. When considered alongside global data on juvenile distribution, this finding strengthens the hypothesis that the Mediterranean Sea functions as a significant breeding and nursery area for basking sharks. Furthermore, the consistent regional presence and lack of evidence for migratory exchange with Atlantic populations suggest the possibility of a distinct Mediterranean population.

Key words: basking shark, *Cetorhinus maximus*, juvenile, Adriatic Sea, Mediterranean Sea, nursery area

OSSERVAZIONI DI UN GIOVANE SQUALO ELEFANTE *CETORHINUS MAXIMUS* IN ADRIATICO CONFERMANO L'IPOTESI DI UNA POPOLAZIONE MEDITERRANEA DISTINTA

SINTESI

Lo squalo elefante Cetorhinus maximus è un grande squalo planctivoro che negli ultimi decenni è stato avvistato sempre più spesso nel Mediterraneo, in particolare nell'Adriatico. Questo studio riporta la cattura accidentale e il rilascio di uno squalo elefante giovane (lunghezza totale stimata ~2 m) nel luglio 2015 vicino all'isola di Meleda (Mljet), nell'Adriatico sud-orientale. L'osservazione è in linea con precedenti registrazioni che indicano la comparsa di esemplari giovani e subadulti durante l'estate, dopo la partenza degli adulti alla fine della primavera. Se considerata insieme ai dati globali sulla distribuzione degli esemplari giovani, questa scoperta rafforza l'ipotesi che il Mediterraneo funga da importante area di riproduzione e crescita per gli squali elefante. Inoltre, la presenza costante nella regione e la mancanza di prove di scambi migratori con le popolazioni dell'Atlantico suggeriscono la possibilità di una popolazione mediterranea distinta.

Parole chiave: squalo elefante, *Cetorhinus maximus*, giovane, Adriatico, Mediterraneo, area di crescita

INTRODUCTION

The basking shark, *Cetorhinus maximus* (Gunnerus, 1765), is a coastal-pelagic, semioceanic, or oceanic species inhabiting boreal to warm-temperate waters along continental and insular shelves. It is found both far offshore and near the coast, sometimes just beyond the surf zone or within enclosed bays (Compagno, 2001; Ebert *et al.*, 2021). This species is highly seasonal, known for its periodic appearances and disappearances in specific locations (Ebert *et al.*, 2021). The number of basking sharks observed in a given area can vary significantly from year to year, with unexplained fluctuations, including occasional population surges ('invasions'). In the Eastern Atlantic, its range extends from Iceland and Norway to North Africa and the Mediterranean (Compagno, 2001; Ebert *et al.*, 2021). While basking shark sightings are widespread throughout the Mediterranean, they are most frequently reported in the Tyrrhenian, Balearic, and Adriatic regions (Mancusi *et al.*, 2005; 2020; Soldo, 2022).

The first record of the basking shark in the Eastern Adriatic area, from where most of the Adriatic records are reported, dates back to 1822. Over the following two centuries, until 2022, 75 records have been documented, with a significant increase in sightings since the early 2000s (Soldo, 2022). In the beginning, the basking shark was relatively rare in the Adriatic, but its occurrence has substantially increased since the start of the 21st century. Records with known precise locations show the occurrence of the basking shark widespread along the Eastern Adriatic coast, with the highest numbers in the Northern Adriatic, particularly Kvarner Bay, known for its rich zooplankton biomass (Soldo *et al.*, 2008; Soldo, 2022). After analyzing the occurrence of the basking sharks and comparing it to fluctuations in zooplankton structure and abundance it was evident that the basking sharks were found in the time of high density of large copepods, particularly *Calanus helgolandicus*, which is considered their major prey (Soldo *et al.*, 2008). Thus, it was suggested that basking sharks migrate from the Mediterranean toward the Northern Adriatic, following water masses carrying specific copepod species that are sufficiently abundant for their feeding (Soldo *et al.*, 2008). Soldo (2022) indicated that basking sharks predominantly appear in late winter and early spring, coinciding with peak copepod abundance. Fewer records exist for autumn and summer with most summer sightings involving juveniles and subadults (<299 cm: juveniles, 300–499 cm: subadults), supporting the hypothesis of seasonal segregation, where younger sharks arrive after adults leave the Adriatic (Soldo, 2022). The only exception to this Adriatic seasonal

pattern was a male juvenile (217 cm, 40 kg) caught in December 2014 in shallow Northern Adriatic waters (20 m depth) (Lipej & Mavrič, 2015). Records of juveniles in the Mediterranean are scarcer than for adults, but the majority corresponds to the summer season pattern (Mancusi *et al.*, 2005). However, there are comparable cases of a juvenile basking shark reported during other periods, e.g. a recent report on a specimen of 259 cm TL that was accidentally captured by a gillnet on 27 February 2024 off the Syrian coast, Eastern Mediterranean (Ali *et al.*, 2024). Even more interestingly, Ali *et al.* (2024) also report the statement from the fishermen that the caught specimen was part of a shoal that contained up to 40 young basking sharks of similar size. Kabasakal (2013) also reported several juvenile records from the Eastern Mediterranean out of the summer season which suggest a possible different behavior pattern of juvenile basking sharks in that area.

In the Mediterranean, which includes the Adriatic Sea, the basking shark is protected under various legislation. Additionally, in Croatian waters, which encompass most of the Eastern Adriatic Sea, the highest level of protection is given to the basking shark as it is declared as a Strictly protected species (Soldo & Lipej, 2022).

The aim of this paper is to contribute to the understanding of basking shark occurrence in the Adriatic by reporting a juvenile record and examining its relevance to the hypothesis of a Mediterranean population.

MATERIAL AND METHODS

On 4 July 2015, a commercial fisherman accidentally caught a juvenile basking shark, *Cetorhinus maximus*, during purse seining for Atlantic bonito, *Sarda sarda* (Bloch, 1793) near the island of Mljet in the Eastern south Adriatic Sea (Fig. 1). The shark was hauled onto the vessel's deck along with the rest of the catch and then promptly released unharmed back into the sea (Fig. 2). According to the fisherman's testimony, the shark immediately swam away vigorously, indicating that the brief period on the deck did not cause it any harm.

Based on visible characteristics of the vessel in the photograph where the juvenile shark is also visible, its size is estimated to be approximately 2 meters, which aligns with the initial information provided by the fisherman. The grey-dark brown shark was easily identified as a juvenile basking shark due to its pointed, hook-like snout, which is longer and more pointed than that of adults, its large subterminal mouth, and the enormous gill slits that nearly encircle the head (Matthews & Parker, 1950). Furthermore, the absence of visible claspers suggests that the shark was female.

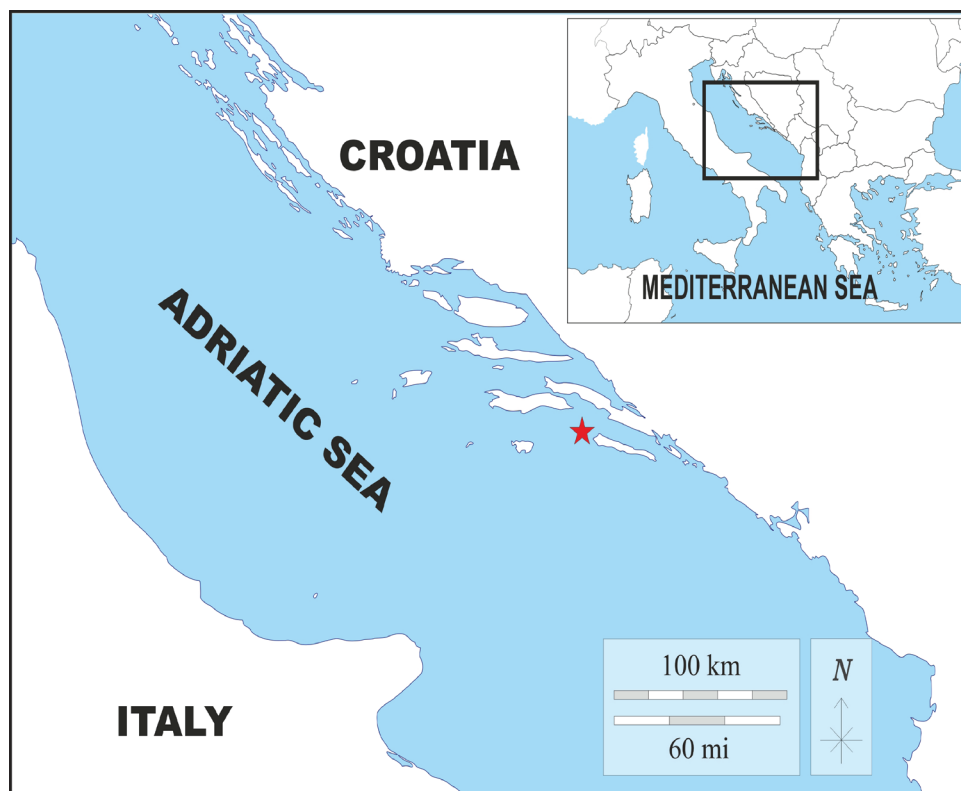


Fig. 1: Location of a catch and release of the juvenile basking shark.

Sl. 1: Zemljevid z lokaliteto ulova in izpusta mladega morskega psa orjaka.

RESULTS AND DISCUSSION

This record aligns with previously documented patterns of basking shark occurrence in the Adriatic Sea, where individuals and even schools have been regularly observed since the beginning of the 21st century. What has also been noted is segregation between adults and young-of-the-year individuals (Soldo *et al.*, 2008; Soldo, 2022). Adult basking sharks typically arrive in the second half of winter and, in the following months are observed near the surface, feeding on dense patches of zooplankton. From mid-spring to late spring, as zooplankton abundance declines, adult basking sharks begin to leave the Adriatic, migrating along the eastern coastline but in deeper waters. Later, with the onset of summer, juvenile sharks emerge from deeper areas and move toward coastal feeding grounds (Soldo *et al.*, 2008; Soldo, 2022). Incorporating this new observation into the existing dataset of summer records (Soldo, 2022) further supports the temporal segregation of age classes. Of the seven summer records, three involved juveniles and three involved subadults (Soldo, 2022).

Notably, Katooka *et al.* (2022) compiled records of juvenile basking sharks worldwide and found that more than 90% originated from the Mediterranean Sea

(84 out of a total of 93 records). Applying the three criteria outlined by Heupel *et al.* (2007) for identifying a nursery area: (1) sharks are more commonly encountered in the area than elsewhere; (2) individuals tend to remain in or return to the area for extended periods; and (3) the area is repeatedly used across years, it can be concluded that the Mediterranean Sea functions as both a breeding and nursery area for the basking shark. This does not necessarily imply that the Mediterranean is the only breeding and nursery ground globally, especially given the species' circum-global distribution across both hemispheres and the existence of juvenile records from regions far beyond the Mediterranean. In the present study, we compiled an updated list of juvenile basking shark records in the Mediterranean Sea. After excluding duplicate entries from Katooka *et al.* (2022) and incorporating new data, the dataset comprises 83 Mediterranean records of individuals measuring up to 4 m in length (Tab. 1). This figure greatly exceeds the number of juvenile records from all other regions combined, highlighting the Mediterranean as a major breeding and nursery ground for the species. A report of the capture of an adult female carrying egg cases off the Syrian coast (Ali *et al.*, 2012), as well as the recent catch of a 259 cm long basking shark in the same area, accompanied



Fig. 2: Photos of the juvenile basking shark on board of the fishing vessel and after the release.
Sl. 2: Fotografije mladega morskega psa orjaka na krovu ribiškega plovila in po izpustu.

by fishermen's reports that the specimen was part of a shoal of up to 40 similarly sized juveniles (Ali *et al.*, 2024), lends further support to this hypothesis.

However, a crucial question remains unanswered: for which population does the Mediterranean serve as a breeding and nursery ground? Due to limited scientific understanding of basking shark biology and ecology, particularly regarding global migration routes, it

is still unclear whether discrete local populations exist or how regional population structures relate to one another. Consequently, it remains unknown whether the basking sharks recorded in the Mediterranean belong to a distinct Mediterranean population or are part of a broader North/Northeast Atlantic population. Nevertheless, there is currently no evidence of migratory exchange between the Mediterranean and

Tab. 1: Records of juvenile and sub-adult (up to 4 m) basking sharks in the Mediterranean Sea.**Tab. 1: Zapisi o pojavljanju mladih in skoraj odraslih (do 4 m) primerkov morskih psuv orjakov v Sredozemskem morju.**

No	Date	Location	TL (m)	Sex	Reference
1	1795	Strait of Messina-Reggio Calabria	2.62	male	Barrull & Mate (1999)
2	1819	Island of Capri-Naples, Italy	2.76	male	Barrull & Mate (1999)
3	11/6/1870	Penzance, Italy	2.76	-	Cornish (1870)
4	25/4/1871	Gulf of Spezia-Liguria, Italy	2.95	male	Pavesi (1874), Barrull & Mate (1999)
5	25/4/1874	Lerici-Gulf of Spezia-Liguria, Italy	2.95	male	Carruccio (1906)
6	10/6/1877	Vado Ligure-Savona, Italy	3.25	male	Pavesi (1878)
7	1880	Messina-Sicily	2.85	female	Barrull & Mate (1999)
8	1880	Camogli – Liguria, Italy	3.58	-	Carruccio (1906)
9	18/6/1880	Messina - Sicily	3.1	female	Senna (1913)
10	3/6/1884	Naples – Campania, Italy	3.5	-	Barrull & Mate (1999)
11	1888	Camogli-Liguria, Italy	1.5	-	Carruccio (1906)
12	10/6/1903	Elba Island – Tuscany, Italy	3.9	male	Barrull & Mate (1999)
13	20/6/1903	Portoferraio - Elba Island – Tuscany, Italy	3.9	male	Barrull & Mate (1999)
14	15/3/1904	Gulf of Alghero-Sassari-Sardinia, Italy	3.37	female	Carazzi (1904)
15	7/3/1905	Naples – Campania, Italy	3.35	female	Barrull & Mate (1999)
16	23/3/1905	Cape Tres Forcas – Melilla, Spain	2.92	-	Escribano (1909)
17	12/5/1907	Faro - Messina – Sicily	2.55	female	Barrull & Mate (1999)
18	23/4/1908	Portulipe - Pozzallo - Ragusa - Sicily	3.6	male	Barrull & Mate (1999)
19	23/7/1908	Island Vis, Croatia	3.1	female	Soldo & Jardas (2002)
20	23/4/1910	Porto Conte – Cerdeña, Italy	2.6	-	Barrull & Mate (1999)
21	4/5/1910	Porto Conte – Cerdeña, Italy	3.3	-	Barrull & Mate (1999)
22	June 1912	Genoa-Liguria, Italy	3.16	male	Barrull & Mate (1999)
23	13/6/1912	Finale Ligure – Liguria, Italy	3.45	female	Vinciguerra (1923)
24	1913	Port of Paglio -Cerdeña, Italy	1.5	-	Ariola (1913)
25	24/5/1913	Quercianella and Castiglione - Tuscany, Italy	2.7	male	Senna (1913)
26	1/6/1913	Port of Vado-Liguria, Italy	2.85	female	Ariola (1913)
27	19/6/1913	Port of Vado Ligure – Liguria, Italy	3.25	male	Ariola (1913)
28	24/7/1913	Portofino – Liguria	2.5	-	Ariola (1913)
29	27/6/1921	S. Michele Beach - Savona – Liguria, Italy	3	-	Vinciguerra (1923)
30	7/10/1921	Island Cres, Croatia	3.2	male	Soldo & Jardas (2002)
31	12/7/1922	Santa Margherita Ligure– Liguria, Italy	3	male	Vinciguerra (1923)
32	September 1922	Cornigliano, Italy	3.7	male	Vinciguerra (1923)
33	10/11/1922	Sesta Levante – Liguria, Italy	3	male	Vinciguerra (1923)
34	5/5/1923	Arebabi Liguria, Italy	3.9	male	Vinciguerra (1923)
35	13/6/1923	Santa Margherita Ligure– Liguria, Italy	3.37	female	Vinciguerra (1923)
36	15/6/1923	Multedo Beach, Italy	2.68	male	Vinciguerra (1923)
37	7/6/1927	Ognina - Syracuse – Sicily	2	female	Monterosso (1931)
38	16/12/1929	Capo Zafferano - Palermo - Sicily	3.19	male	Barrull & Mate (1999)
39	27/12/1929	Ras Falcon, Tunisia	3.75	male	Capapé <i>et al.</i> (2003)
40	25/11/1930	Porticello - Palermo - Sicily	3.05	male	Barrull & Mate (1999)

41	25/5/1931	Balestrate - Palermo – Sicily	2.85	male	Barrull & Mate (1999)
42	6/2/1931	Plaia - Catania - Sicily	3.4	female	Monterosso (1931)
43	10/7/1937	Lumbarda-Korčula, Croatia	3.5	-	Soldo & Jardas (2002)
44	19/5/1939	Palma, Spain	3	male	Navarro (1943)
45	1942	Palma, Spain	2	-	Navarro (1943)
46	October 1957	Valencia, Spain	3.3	-	López (1963)
47	11/1/1965	Acre, Israel	2.67	-	Barrull & Mate (1999)
48	7/3/1965	Acre, Israel	2.59	-	Barrull & Mate (1999)
49	1968	Ston, Croatia	2.5	-	Lipej <i>et al.</i> (2000)
50	February 1969	Ses Caletes des Cap Pinar – Mallorca, Spain	3.4	female	Barrull & Mate (1999)
51	January-March 1971	Israel coast	259-261	-	
52	1974	Trieste, Italy	3.92	-	Lipej <i>et al.</i> (2000)
53	1979	Benicarló – Castellón, Spain	4	male	Barrull & Mate (1999)
54	1980	Gulf of Tunis	2.7	male	Capapé <i>et al.</i> (2003)
55	14/2/1981	Bar, Montenegro	4	-	Soldo & Jardas (2002)
56	18/6/1981	Ičići, Croatia	2.65	-	Soldo & Jardas (2002)
57	August 1981	Ras Fartas – Gulf of Tunis	3.5	male	Capapé <i>et al.</i> (2003)
58	18/4/1987	Antalya bay, Turkey	4	-	Kabasakal (2004)
59	7/2/1991	Haifa, Israel	2.5	-	Barrull & Mate (1999)
60	10/8/1992	Sant Pere Pescador – Girona, Spain	2.5	-	Barrull & Mate (1999)
61	19/3/1995	Gulf of Santa Eufèmia – Calabria, Italy	3	male	Barrull & Mate (1999)
62	24/4/1997	Vittoria - Ragusa - Sicily	3.2	-	Barrull & Mate (1999)
63	11/5/1998	Lido Marza. Pozzallo - Ragusa – Sicily	2.48	male	Barrull & Mate (1999)
64	June 1998	Strait of Messina-Sicily	4	-	Barrull & Mate (1999)
65	4/3/2000	Offshore Annaba, Algeria	3.3	female	Capapé <i>et al.</i> (2003)
66	22/5/2000	Piran, Slovenia	2.99	male	Lipej <i>et al.</i> (2000)
67	10/6/2000	Camogli-Liguria, Italy	2.66	male	Barrull & Mate (1999)
68	19/7/2000	Piran, Slovenia	2.49	male	Lipej <i>et al.</i> (2000)
69	30/12/2006	Iskenderun Bay, Turkey	3	-	Bilecenoglu <i>et al.</i> (2013)
70	February 2007	Gulf of Gabès	2.42	female	Enajjar <i>et al.</i> (2019)
71	29/4/2007	Lumbarda-Korčula, Croatia	2.7	-	Soldo (2022)
72	11/7/2008	Port of Rijeka, Croatia	2.5	-	Soldo (2022)
73	11/6/2010	Ancona, Italy	3.65	male	This study
74	29/4/2011	Mošćenička draga	3.7	-	Soldo (2022)
75	7/4/2012	Erdemli Coast, Turkey	2.36	male	Bilecenoglu <i>et al.</i> (2013)
76	12/5/2013	Famagusta harbour, Cyprus	4	-	Kabasakal (2013)
77	20/3/2014	Mersin Bay, Turkey	2.45	female	Ergüden <i>et al.</i> (2020)
78	25/12/2014	Piran, Slovenia	2.17	male	Tsiamis <i>et al.</i> (2015)
79	4/6/2015	Island Mljet, Croatia	2	female	This study
80	6/5/2017	Plage de Port Leucate, France	4	-	Carpaye-Taïlamée (2019)
81	7/5/2017	Banyuls sur Mer, France	4	-	Carpaye-Taïlamée (2019)
82	8/7/2017	Port des Embiez, France	2.5	-	Carpaye-Taïlamée (2019)
83	27/2/2024	South of Lattakia, Syria	2.59	-	Ali <i>et al.</i> (2024)

Atlantic populations. Basking sharks in the Mediterranean are observed during the same periods as those in the Northeast Atlantic, and the seasonal distribution patterns appear consistent across both regions (Soldo *et al.*, 2008). This temporal overlap suggests the existence of regionally isolated populations. Likewise, studies in the Northeast Atlantic, particularly around Britain, have reported basking shark movements confined to the Atlantic, with no indications of individuals migrating into the Mediterranean Sea (Sims *et al.*, 2005; Doherty *et al.*, 2017, 2019; Dolton *et al.*, 2020). Consequently, it can be assumed that basking sharks in the Mediterranean constitute a distinct regional population, but this hypothesis requires further verification through more focused and multidisciplinary studies. Comprehensive population genetic analyses should be prioritized as it is

needed to determine whether Mediterranean basking sharks form a distinct genetic population. In parallel, long-term satellite tagging programs are essential to monitor movements of individual sharks, particularly to detect any connectivity between Mediterranean and Atlantic populations.

In conclusion, the high number of juvenile sightings in the Mediterranean, the apparent lack of migratory exchange with the Atlantic, and the consistent regional occurrence patterns all support the hypothesis of a distinct Mediterranean population of basking sharks. To validate this, an integrated research strategy combining genetic, ecological, and telemetry-based approaches is urgently needed. Such efforts are not only critical for advancing our understanding of basking shark population structure but also for producing effective regional conservation and management strategies.

OPAZOVANJA MLADEGA MORSKEGA PSA ORJAKA (*CETORHINUS MAXIMUS*)
V JADRANSKEM MORJU PODPIRAJO HIPOTEZO O LOČENI
SREDOZEMSKI POPULACIJI

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POVZETEK

Morski pes orjak (*Cetorhinus maximus*) je velik planktivoren morski pes, katerega število opažanj v Sredozemskem morju se je v zadnjih desetletjih povečalo, zlasti v Jadranskem morju. Avtor poroča o naključnem ulovu in izpustu mladega morskega psa orjaka (ocenjene skupne dolžine ~2 m) julija 2015 v bližini otoka Mljet v vzhodnem južnem Jadranu. Opazovanje se ujema s prejšnjimi zapisi, ki kažejo na pojav mladih in skoraj odraslih primerkov poleti, po odhodu odraslih pozno spomladi. Če to ugotovitev obravnavamo skupaj z globalnimi podatki o razširjenosti mladih primerkov, to podpira hipotezo, da Sredozemsko morje deluje kot pomembno območje za razmnoževanje in odraščanje mladih primerkov morskih psov orjakov. Poleg tega dosledna regionalna prisotnost in pomanjkanje dokazov o migracijski izmenjavi z atlantskimi populacijami kažeta na možnost obstoja ločene sredozemske populacije.

Ključne besede: morski pes orjak, *Cetorhinus maximus*, Jadransko morje, Sredozemsko morje, mladostni primerek, jaslice

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