ANNALES

Anali za istrske in mediteranske študije
Annali di Studi istriani e mediterranei
Annals for Istrian and Mediterranean Studies
Series Historia Naturalis, 36, 2026, 1

UDK 5 Annales, Ser. hist. nat., 36, 2026, 1, pp. 1-256, Koper 2026 ISSN1408-533X

UDK 5

ISSN 1408-533X
e-ISSN 2591-1783

ANNALES

Anali za istrske in mediteranske študije
Annali di Studi istriani e mediterranei
Annals for Istrian and Mediterranean Studies

Series Historia Naturalis, 36, 2026, 1

KOPER 2026

Anali za istrske in mediteranske študije - Annali di Studi istriani e mediterranei - Annals for Istrian and Mediterranean Studies

ISSN 1408-533X
e-ISSN 2591-1783
UDK 5
Letnik 36, leto 2026 številka 1

Tisk/*Stampa/Print:* Založništvo PADRE d.o.o.

Izdajatelja/*Editori/Published by:* Zgodovinsko društvo za južno Primorsko - Koper / *Società storica del Litorale - Capodistria*©
Inštitut IRRIS za raziskave, razvoj in strategije družbe, kulture in okolja / *Institute IRRIS for Research, Development and Strategies of Society, Culture and Environment / Istituto IRRIS di ricerca, sviluppo e strategie della società, cultura e ambiente*©

Sedež uredništva/*Sede della redazione/ Address of Editorial Board:* Nacionalni inštitut za biologijo, Morska biološka postaja Piran / *Istituto nazionale di biologia, Stazione di biologia marina di Pirano / National Institute of Biology, Marine Biology Station Piran*
SI-6330 Piran /*Pirano*, Fornače/*Fornace* 41, tel.: +386 5 671 2900, fax +386 5 671 2901;
e-mail: annalesSHN@nib.si, *internet:* www.zdjp.si

Redakcija te številke je bila zaključena 20. 06. 2026.

Sofinancirajo/*Supporto finanziario/ Financially supported by:* Javna agencija za znanstveno-raziskovalno in inovacijsko dejavnost Republike Slovenije (ARIS)

Annales - Series Historia Naturalis izhaja dvakrat letno.

Naklada/*Tiratura/Circulation:* 300 izvodov/copie/copies

Revija Annales, Series Historia Naturalis je vključena v naslednje podatkovne baze / *La rivista Annales, series Historia Naturalis è inserita nei seguenti data base / Articles appearing in this journal are abstracted and indexed in:* BIOSIS-Zoological Record (UK); Aquatic Sciences and Fisheries Abstracts (ASFA); Elsevier B.V.: SCOPUS (NL); Directory of Open Access Journals (DOAJ).

Navodila avtorjem in vse znanstvene revije in članki so brezplačno dostopni na spletni strani https://zdjp.si/en/p/annalesshn/
The submission guidelines and all scientific journals and articles are available free of charge on the website https://zdjp.si/en/p/annalesshn/
Le norme redazionali e tutti le riviste scientifiche e gli articoli sono disponibili gratuitamente sul sito https://zdjp.si/en/p/annalesshn/

ANNALES · Ser. hist. nat. · 36 · 2026 · 1

Anali za istrske in mediteranske študije - Annali di Studi istriani e mediterranei - Annals for Istrian and Mediterranean Studies

UDK 5 Letnik 36, Koper 2026, številka 1 ISSN 1408-53 3X

e-ISSN 2591-1783

VSEBINA / *INDICE GENERALE / CONTENTS*

received: 2026-01-18 DOI 10.19233/ASHN.2026.13

DISTRIBUTION OF *ODONTASPIS FEROX* IN THE MEDITERRANEAN SEA: INSIGHTS FROM SPATIAL AND TEMPORAL ANALYSES

Hakan KABASAKAL
Hydrobiological Research Association (HİDRA), Gökçeada, Çanakkale, Türkiye
e-mail: kabasakal.hakan@gmail.com

ABSTRACT

This study provides an updated synthesis of the occurrence and distribution of smalltooth sandtiger shark, Odontaspis ferox*, in the Mediterranean Sea, based on 46 records spanning the period 1964–2025. Occurrence records were found to be unevenly distributed across the basin, with a pronounced concentration in the Aegean Sea (GSA 22), which accounted for nearly half of all records. Kernel density estimation further supported this spatial clustering. Temporal analysis revealed a significant increase in the annual number of records, reflecting both intensified research efforts and a growing contribution of citizen science facilitated by digital technologies. Although some records from Libyan and Syrian waters could not be included due to the lack of precise locality data, the present compilation represents a substantial increase compared to earlier assessments.*

Key words: smalltooth sandtiger, distribution, hot spot, kernel density estimation, eastern Mediterranean

DISTRIBUZIONE DI *ODONTASPIS FEROX* NEL MAR MEDITERRANEO: APPROFONDIMENTI DA ANALISI SPAZIALI E TEMPORALI

SINTESI

Lo studio fornisce una sintesi aggiornata della presenza e distribuzione del cagnaccio, Odontaspis ferox*, nel Mediterraneo, basata su 46 segnalazioni che coprono il periodo 1964–2025. Le segnalazioni risultano distribuite in modo non uniforme nel bacino, con una marcata concentrazione nel Mar Egeo (GSA 22), che rappresenta quasi la metà di tutti i ritrovamenti. L'analisi tramite stima della densità kernel ha ulteriormente confermato questa distribuzione spaziale. L'analisi temporale ha evidenziato un aumento significativo del numero annuale di segnalazioni, riflettendo sia l'intensificarsi degli sforzi di ricerca sia il crescente contributo della citizen science, facilitato dalle tecnologie digitali. Sebbene alcune segnalazioni provenienti dalle acque libiche e siriane non abbiano potuto essere incluse a causa della mancanza di dati precisi sulla località, la presente raccolta rappresenta un incremento sostanziale rispetto alle valutazioni precedenti.*

Parole chiave: cagnaccio, distribuzione, hotspot, stima della densità kernel, Mediterraneo orientale

INTRODUCTION

The smalltooth sandtiger shark, *Odontaspis ferox* (Risso, 1810), is a large lamniform shark from the family Odontaspididae (Elasmobranchii: Lamniformes) (WoRMS Editorial Board, 2026). The species exhibits a cosmopolitan yet highly discontinuous distribution, occurring sporadically in the Atlantic, Pacific, and Indian Oceans, as well as in the Mediterranean Sea (Ebert *et al.*, 2021; Barone *et al.*, 2022). Despite its broad geographic range, *O. ferox* is rarely encountered and is typically known from isolated occurrence records. The species inhabits warm-temperate and tropical waters, occupying continental and insular shelves and upper slopes at depths ranging from approximately 10 m to more than 1,015 m, although it is more frequently recorded below 300 m (Ebert *et al.*, 2021). It is primarily demersal and often associated with steep and narrow topographic features, such as seamounts, islands, and the outer margins of continental shelves (Ebert *et al.*, 2021). The maximum recorded total length (TL) reaches up to 450 cm in females and 344 cm in males (Ebert *et al.*, 2021).

Within the Mediterranean Sea, the rarity of *O. ferox* is particularly pronounced. Fergusson *et al.* (2008) documented only 14 confirmed records from the basin during the period between 1964 and 2008, highlighting the exceptional infrequency of the species in the region. More recent studies have suggested that the number of Mediterranean records may be higher than previously assumed, likely reflecting increased observation effort and improved reporting rather than a true increase in abundance (Kabasakal *et al.*, 2024; Pyloridou *et al.*, 2025). Nevertheless, confirmed observations remain extremely limited, reinforcing the perception of *O. ferox* as one of the rarest lamniform sharks in the Mediterranean Basin.

Given the species' extreme rarity, fragmented distribution, and declining population trend—particularly within the semi-enclosed and heavily impacted Mediterranean Sea, each confirmed occurrence of *O. ferox* provides critical insight into its distribution and conservation status. The present study provides a comprehensive review of Mediterranean records of *O. ferox*, supported by spatial and temporal analyses, and establishes an objective framework for evaluating occurrence patterns across regions and over time. This approach highlights areas of regional importance, reveals trends in population dynamics, and strengthens the reliability of distributional assessments, providing robust, data-driven insights to guide conservation strategies for this highly threatened and elusive shark.

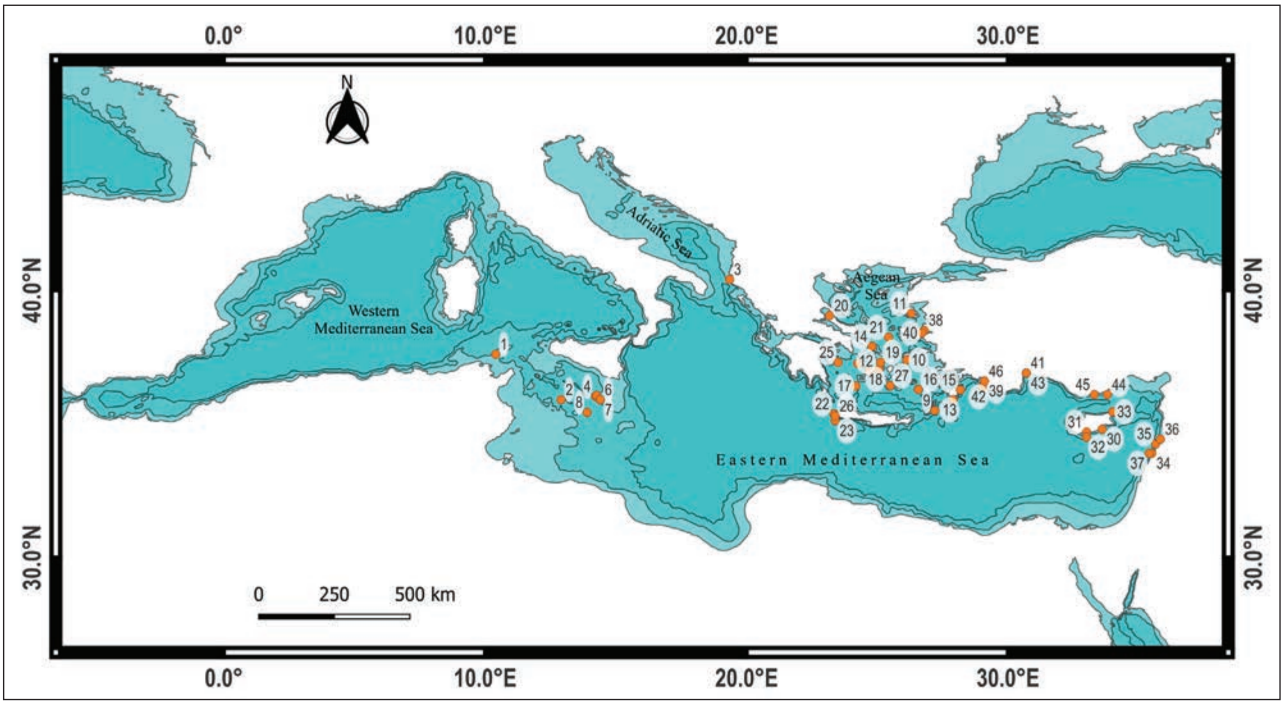

Fig. 1. Distribution of *Odontaspis ferox* ***in the Mediterranean Sea based on published records; each dot represents a single published occurrence. The numbers in the labels correspond to those in the "No" column of Table 1.***
Sl. 1: Prikaz razširjenosti vrste *Odontaspis ferox* ***v Sredozemlju glede na objavljene vire. Vsaka pika označuje posamezen podatek o pojavljanju, številke napisov pa se ujemajo z zaporednimi številkami (stolpec »No.«) v tabeli 1.***

MATERIAL AND METHODS

Study Area

The Mediterranean Sea is recognized as a marine biodiversity hotspot situated between Africa, Europe, and Asia (Coll *et al.*, 2011). It is connected to the Atlantic Ocean through the Strait of Gibraltar, to the Sea of Marmara and the Black Sea via the Dardanelles, and to the Red Sea through the Suez Canal (Fig. 1). The basin reaches a maximum depth of 5,267 m and has an average depth of approximately 1,460 m. A shallow, approximately 400 m deep ridge in the Strait of Sicily separates the Mediterranean Sea into western and eastern sub-basins (Coll *et al.*, 2011; Serena & Soldo, 2024). According to the geographical subdivision of the Mediterranean Sea into Geographical Subareas (GSAs) proposed by the General Fisheries Commission for the Mediterranean (GFCM, 2018), the occurrence localities of additional records compiled from literature fall within GSAs 13 (Gulf of Hammamet), 15 (Malta), 16 (southern Sicily), 18 (southern Adriatic Sea), 22 (Aegean Sea), 23 (Crete), 24 (northern Levantine Sea), 25 (Cyprus), and 27 (eastern Levantine Sea).

Data Acquisition

To evaluate the occurrence of *O. ferox* within GSAs 13, 15, 16, 18, 22, 23, 24, 25, and 27, previously published records were compiled from the scientific literature (Geldiay, 1969; Fergusson *et al.*, 2008; Corsini-Foka, 2009; Kabasakal & Bayrı, 2019; Akbora *et al.*, 2019; Zaferiaki *et al.*, 2019; Bariche & Fricke, 2020; Kabasakal & Bilecenoğlu, 2020; Ben Amor *et al.*, 2020; Moutopoulos *et al.*, 2022; Soldo *et al.*, 2022; Kabasakal *et al.*, 2024; Pyloridou *et al.*, 2025). The literature review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page *et al.*, 2021). To avoid multiple inclusion of the same individual, the original source reporting each record was used as the primary reference.

A single database was compiled including all available Mediterranean records derived from peer-reviewed publications, incorporating information on locality (country and GSA), date of capture or observation, depth, reported total length (TL), sex, remarks (*e.g.*, fishing gear), and reference (Tab. 1). Distribution

Tab. 1. Review of** Odontaspis ferox **in the Mediterranean Sea based on published records.
Tab. 1: Pregled razširjenosti vrste** Odontaspis ferox **v Sredozemskem morju na podlagi objavljenih podatkov.

No	Year	Country	Location	GSA	Size (cm)	Sex	Depth (m)	Evidence	Remarks	Reference
1	1985	Italy	Skerki Bank, Sicilian Channel	16	410	F	N/A	Catch	Captured in demersal trawl fishery	Fergusson *et al.* (2008)
2	1991	Italy	Isola di Linosa, Pelagic Islands	16	230	F	10-40	Catch	Captured in bottom-set gillnet	Fergusson *et al.* (2008)
3	2021	Albania	Pasha Liman, Bay of Vlore	18	300	F	N/A	N/A	N/A	Soldo *et al.* (2022)
4	1998	Malta	Xlendi Bay, Gozo Island	15	353	F	100	Catch	Captured in bottom-set gillnet	Fergusson *et al.* (2008)
5	1999	Malta	Marsalforn, Gozo Island	15	400	N/A	N/A	N/A	N/A	Fergusson *et al.* (2008)
6	2002	Malta	N/A	15	298	N/A	N/A	Catch	Captured in bottom longline	Fergusson *et al.* (2008)
7	2003	Malta	N/A	15	382	F	N/A	Catch	Captured in bottom longline	Fergusson *et al.* (2008)
8	2020	Tunisia	Pantelleria Island	13	N/A	N/A	400-1,100	Catch	Captured in bottom longline	Ben Amor *et al.* (2020)
9	1968	Greece	Karpathos Island	22	340	F	N/A	Catch	Captured in demersal longline fishery	Fergusson *et al.* (2008)
10	1980	Greece	Ikaria Island	22	N/A	N/A	N/A	Catch	Photograph is published in the reference	Moutopoulos *et al.* (2022)
11	1981	Greece	Mytilene	22	N/A	N/A	N/A	Catch	Photograph is published in the reference	Moutopoulos *et al.* (2022)
12	2001	Greece	Sifnos Island, Cyclades	22	165	F	200	Catch	Captured in swordfish fishery	Fergusson *et al.* (2008)
13	2007	Greece	off southern Rhodes Island	22	250	N/A	ca. 70	Catch	Captured in demersal trawl fishery	Corsini-Foka (2009)
14	2011	Greece	Andros	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
15	2012	Greece	Rhodes	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)

16	2012	Greece	Kandelioussa	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
17	2012	Greece	Milos	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
18	2013	Greece	Paros	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
19	2014	Greece	Tinos	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
20	2015	Greece	Kastri	22	285	N/A	N/A	N/A	Captured in demersal fishery	Zaferiaki *et al.* (2019)
21	2015	Greece	Chios	22	377	N/A	N/A	N/A	Captured in demersal fishery	Zaferiaki *et al.* (2019)
22	2015	Greece	Crete	23	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
23	2017	Greece	Crete	23	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
24	2017	Greece	Kythnos	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
25	2021	Greece	Hydra	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
26	2022	Greece	Crete	23	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
27	2024	Greece	Amorgos	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
28	2025	Greece	Kandelioussa	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
29	2025	Greece	Kandelioussa	22	N/A	N/A	N/A	N/A	Occurrence record	Pyloridou *et al.* (2025)
30	1999	Cyprus	off Larnaca	25	300	N/A	250	Catch	Captured in bottom-set gillnet fishery	Fergusson *et al.* (2008)
31	1999	Cyprus	off Limassol	25	300	N/A	100	Catch	Captured in demersal longline fishery	Fergusson *et al.* (2008)
32	1999	Cyprus	off Limassol	25	160	N/A	100	Catch	Captured in demersal longline fishery	Fergusson *et al.* (2008)
33	2018	Cyprus	off Yeni Erenköy	25	430	F	41	Catch	Captured during the fishing of *Seriola dumerili* by a local fisher and sold to a fish restaurant	Akbora *et al.* (2019)
34	1964	Lebanon	off Beirut	27	283	M	100	N/A	N/A	Fergusson *et al.* (2008)
35	1995	Lebanon	off Batroun	27	N/A	N/A	N/A	N/A	Occurrence record	Bariche & Fricke (2020)
36	2014	Lebanon	off Tripoli	27	N/A	N/A	N/A	N/A	Occurrence record	Bariche & Fricke (2020)
37	2015	Lebanon	off Beirut	27	N/A	N/A	N/A	N/A	Occurrence record	Bariche & Fricke (2020)
38	1969	Türkiye	İzmir Bay	22	N/A	N/A	N/A	N/A	Only locality record	Geldiay (1969)
39	2002	Türkiye	Fethiye Bay	22	200	N/A	N/A	Catch	Captured in demersal trawl fishery	Fergusson *et al.* (2008)
40	2004	Türkiye	Urla, İzmir Bay	22	190	F	30	Catch	Captured in artisanal fishery, type of the fishing gear not known	Fergusson *et al.* (2008)
41	2009	Türkiye	Antalya Bay	24	ca. 400	N/A	N/A	Catch	Type of fishing gear is unknown; the specimen cut to pieces and sold	Kabasakal *et al.* (2024)
42	2013	Türkiye	Fethiye Bay	22	ca. 120	F	N/A	Catch	Type of fishing gear is unknown; shipped to İstanbul Fishmarket and auctioned	Kabasakal *et al.* (2024)
43	2019	Türkiye	Antalya Bay	24	ca. 400	F	100 to 120	Catch	Captured in demersal trawl fishery	Kabasakal & Bayrı (2019)
44	2019	Türkiye	Taşucu, Mersin	24	ca. 400	F	N/A	Catch	Captured in demersal trawl fishery and sold	Kabasakal & Bilecenoğlu (2020)
45	2021	Türkiye	Bozyazı, Mersin	24	ca. 350	F	N/A	Catch	Captured in demersal trawl fishery and sold	Kabasakal *et al.* (2024)
46	2022	Türkiye	Fethiye Bay	22	272	M	N/A	Catch	Type of fishing gear is unknown; the specimen cut to pieces and sold; jaws are preserved in the personal collection of Mr. Erdi Bayrı	Kabasakal *et al.* (2024)

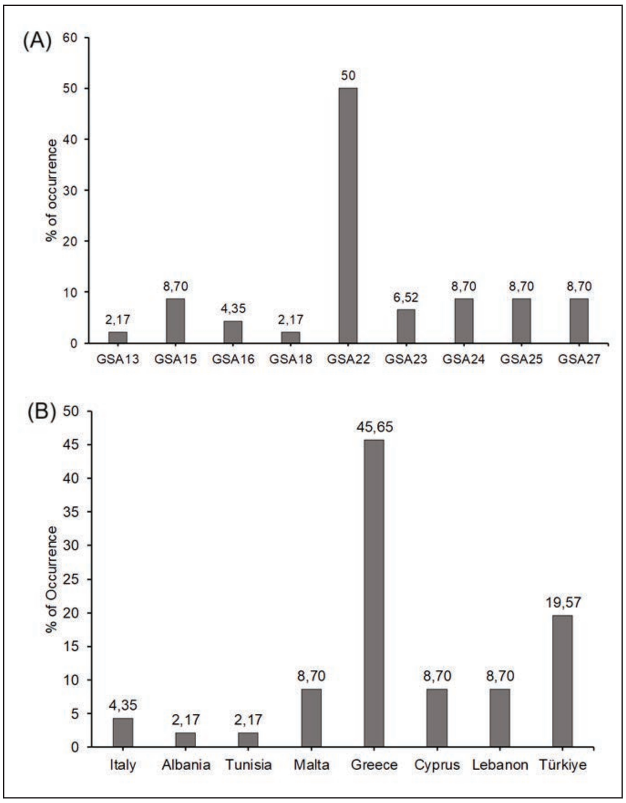

Fig. 2. Percentages of occurrence records by GSAs (a) and countries (b).
Sl. 2: Odstotni deleži podatkov o pojavljanju po geografskih podobmočjih (GSA) (a) in državah (b).

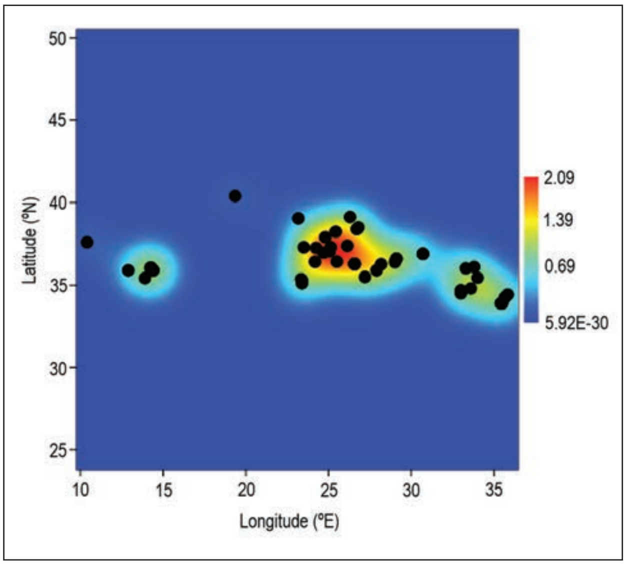

Fig. 3. Kernel density estimation (KDE) showing the spatial distribution of* Odontaspis ferox *occurrence records based on published data. The legend on the right represents occurrence density based on latitude and longitude records.
Sl. 3: Ocena gostote jedra (KDE), ki prikazuje prostorsko razširjenost zapisov o pojavljanju vrste* Odontaspis ferox *na podlagi objavljenih virov. Legenda na desni prikazuje gostoto pojavljanja glede na podatke o zemljepisni širini in dolžini.

mapping was performed using centroid coordinates of published locality records, with each point representing a single individual, and visualized using the open-source geospatial software QGIS version 3.40.

Spatiotemporal Analysis

The geographical distribution of occurrence records was analyzed to identify hot and cold spots, under the assumption that areas with higher record densities may indicate suitable habitats (Bargnesi *et al.*, 2020a). For this purpose, kernel density estimation (KDE) was applied using the software PAST, version 4.03 (Hammer *et al.*, 2001). The KDE was implemented as a smoothing estimator of the histogram based on a Gaussian kernel, with the spatial smoothing parameter determined according to Silverman's rule of thumb (Silverman, 1986). The analysis was based on two-dimensional spatial data, incorporating the number of occurrence records at given geographic coordinates (longitude and latitude).

Temporal trends in annual occurrence records were assessed using both the Mann–Kendall trend test and linear regression analysis, following contemporary approaches for the analysis of ecological time-series data (Warton, 2022). Differences in the distribution of individual records among geographical subareas across years were tested using a chi-square test of independence (Warton, 2022). Differences in the number of recorded individuals among geographical subareas and countries were assessed using the Kruskal–Wallis H test, followed by pairwise Mann–Whitney U tests where appropriate, as the data did not meet assumptions of normality (Warton, 2022). All statistical analyses were performed using PAST software, version 4.03 (Hammer *et al.*, 2001). Statistical significance was assessed at a significance level of p = 0.05 (Parab & Bhalerao, 2010). Raw data will be made available on reasonable request.

RESULTS AND DISCUSSION

Spatial occurrence of *Odontaspis ferox*

Following the methodologies described above, a total of 46 occurrence records from the period 1964–2025 were included in the present review (Tab. 1). The distribution of *Odontaspis ferox* in the Mediterranean Sea based on published records is illustrated in the map (Fig. 1). The records were unevenly distributed across the basin, with a strong concentration in the Aegean Sea (GSA 22), which accounted for 50% of all records (n = 23) (Fig. 2). This spatial clustering was further supported by kernel density estimation (KDE) analysis, indicating a high concentration of occurrences between 25–30°E longitude and 35–40°N latitude (Fig. 3). GSA 22 differed significantly from all other GSAs (Kruskal–Wallis test: $p < 0.05$), as confirmed by pairwise comparisons with the other subareas (Mann–Whitney U test: $p < 0.05$).

Of the total records, 45.65% were reported from Greek waters, followed by Türkiye with 19.57% (Fig. 2). The distribution of occurrence records among countries also differed significantly (Kruskal–Wallis test: $p < 0.05$ for all countries). Pairwise comparisons using the Mann–Whitney U test showed significant differences between Greece and all other countries except Türkiye ($p < 0.05$), and between Türkiye and all other countries except Greece ($p < 0.05$), whereas no significant difference was detected between Greece and Türkiye ($p > 0.05$; $p = 0.15$).

Temporal occurrence of *Odontaspis ferox*

The temporal distribution of occurrence records among geographical subareas also displayed significant differences (chi-square test: $p < 0.05$; $p = 0.019$). The Mann–Kendall trend test revealed a statistically significant increasing trend in the annual number of records across the entire study area ($p < 0.001$; Fig. 4). Results of the Mann–Kendall trend analysis for individual countries are presented in Table 2. Although statistically significant increasing trends were detected for Greece ($p < 0.001$) and Türkiye ($p < 0.008$), the trend observed for GSA 22 did not reach statistical significance ($p > 0.05$) (Tab. 2).

The present study provides an updated overview of the distribution of *O. ferox* in the Mediterranean Sea. To address this objective, spatial and temporal analyses of occurrence records were conducted, based on density and trend analyses of published data. The compiled records suggest that the eastern Mediterranean Sea, and especially the Aegean Sea within GSAs 23–27, is gaining increasing importance for the persistence of the species, emphasizing the regional significance of the eastern Mediterranean within the global distribution range of *O. ferox*.

The conservation of sharks and their relatives (Chondrichthyes) has become an increasing concern, as nearly one-third of species are currently threatened with extinction (Dulvy *et al.*, 2021). Historically, lethal sampling was considered the most effective method for obtaining life-history information (Walker, 1998). However, growing awareness of the ecological importance of sharks, alongside a shift in public perception of large apex predators from fearsome animals to charismatic megafauna (Mazzoldi *et al.*, 2019), has led to a widespread adoption of non- or minimally invasive research methods

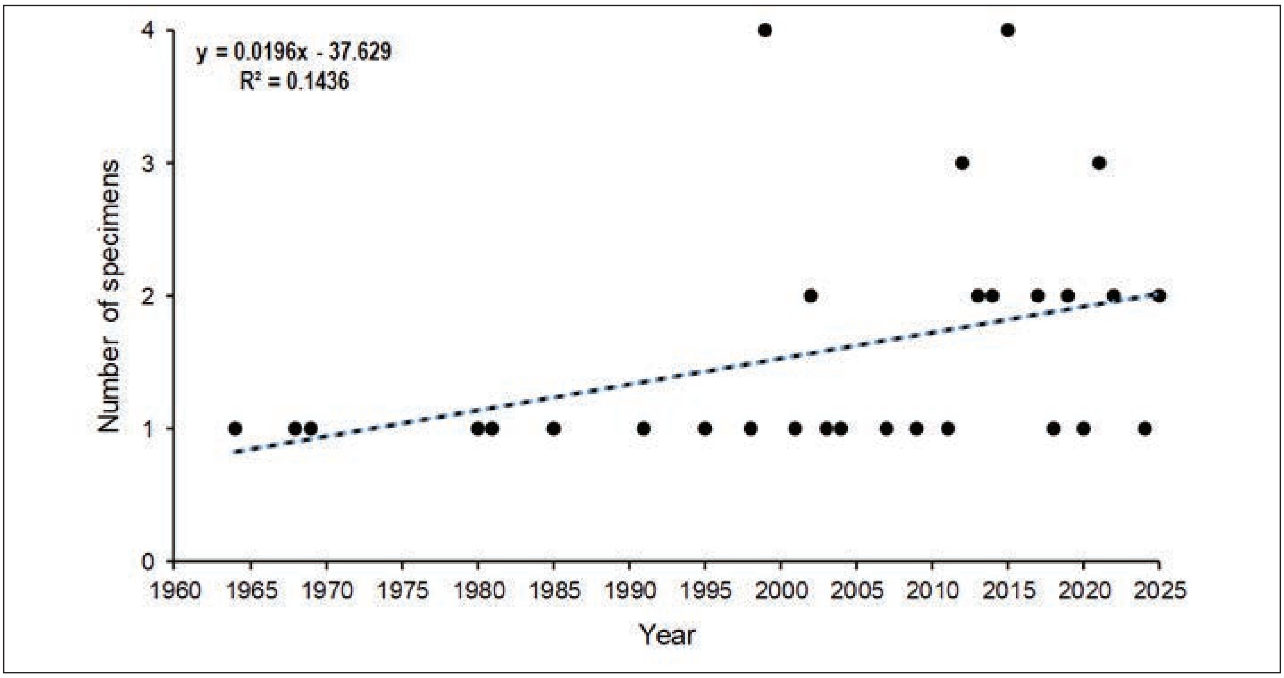

Fig. 4. Annual trend in occurrence records of** Odontaspis ferox **(1964–2025).
Sl. 4: Letni trend zapisov o pojavljanju vrste** Odontaspis ferox **v obdobju 1964–2025.

(Heupel & Simpfendorfer, 2010). Visual techniques, including photography and videography, now allow researchers to study population composition, abundance, residency, movement, demography, and social behavior without harming individuals. In the Mediterranean, such approaches have been successfully applied to investigate the behavior of endangered batoids, identify aggregation sites, and assess trophic interactions, thereby demonstrating their effectiveness in ecological and conservation research (Kabasakal, 2009; Bilgili & Kabasakal, 2023; Tiralongo *et al.*, 2025).

Citizen science (CS) programs have further expanded the reach of these non-invasive approaches, enabling broader data collection while actively engaging the public in conservation efforts (Gibson *et al.*, 2019; Ferretti *et al.*, 2025). CS initiatives are particularly valuable for documenting rare or elusive Mediterranean sharks that are difficult to detect through conventional scientific surveys (Bargnesi *et al.*, 2020b). In addition, the growing involvement of CS in natural resource management allows the expansion of research effort at relatively low cost while fostering meaningful public engagement (Gibson *et al.*, 2019; Ferretti *et al.*, 2025). When carefully coordinated and combined with non-invasive visual methods, CS contributes significantly to long-term monitoring programs, improving both the spatial and temporal coverage of population assessments and supporting evidence-based management of threatened elasmobranch species.

Recent studies clearly demonstrate that CS has contributed to a marked increase in the number of records of *O. ferox* in the Mediterranean Sea (Kabasakal *et al.*, 2024; Pyloridou *et al.*, 2025). Notably, 61.5% (n = 16) of the most recent unpublished records of the species originated from CS efforts (Pyloridou *et al.*, 2025). Nevertheless, as emphasized by Gibson *et al.* (2019), CS-derived data are sometimes viewed with caution due to potential limitations in data collection rigor and validation procedures. This concern was also highlighted by Soldo (2026) in a recent study addressing a debated record of a lamnid shark from the Adriatic Sea, in which the author recommended that CS-derived records of rare elasmobranchs should be supported by high-quality photographic documentation of diagnostic features, allowing independent evaluation by taxonomic experts.

Since the comprehensive review by Fergusson *et al.* (2008), knowledge of the contemporary occurrence and distribution of *O. ferox* in the Mediterranean Sea and adjacent waters has increased markedly. Owing to the efforts of several researchers in the eastern Mediterranean region, the number of records of *O. ferox* from the waters of Greece (Corsini-Foka, 2009; Zaferiaki *et al.*, 2019; Moutopoulos *et al.*, 2022; Pyloridou *et al.*, 2025), Türkiye (Kabasakal & Bayrı, 2019; Kabasakal & Bilecenoğlu, 2020; Kabasakal *et al.*, 2024), Lebanon (Bariche & Fricke, 2020), and Cyprus (Akbora *et al.*, 2019) has increased by 90.4%, 80%, 75%, and 33.3%, respectively. Comparable research efforts in several other geographical subareas (GSAs) of the Mediterranean Sea have also substantially improved understanding of the contemporary occurrence of *O. ferox* in the region (Ben Amor *et al.*, 2020; Soldo *et al.*, 2022; Shakman *et al.*, 2023).

Tab. 2. Results of the Mann–Kendall trend test for *Odontaspis ferox* ***occurrence records by country and geographical subarea (GSA). S: Mann–Kendall test statistic indicating the direction of a monotonic trend; Z: standardized test statistic used to assess the significance of the trend; p: p-value; Y: yes; N: no.***

Tab. 2: Rezultati Mann–Kendallovega testa trenda za podatke o pojavljanju vrste *Odontaspis ferox* ***po državah in geografskih podobmočjih (GSA). S: statistika Mann–Kendallovega testa, ki nakazuje smer monotonega trenda; Z: standardizirana testna statistika, uporabljena za ocenjevanje značilnosti trenda; p: p-vrednost; Y: da; N: ne.***

	S	Z	P	Significant trend Y/N
Italy	-26	-0.498	0.618	N
Malta	48	0.673	0.501	N
Tunisia	51	1.397	0.162	N
Albania	53	1.453	0.146	N
Greece	405	3.294	**0.001**	**Y**
Türkiye	267	2.654	**0.008**	**Y**
Cyprus	55	1.076	0.282	N
Lebanon	20	0.272	0.785	N
GSA13	19	0.975	0.330	N
GSA15	-44	-1.225	0.221	N
GSA16	-40	-1.518	0.129	N
GSA18	21	1.083	0.279	N
GSA22	45	0.798	0.425	N
GSA23	43	1.358	0.175	N
GSA24	63	1.763	0.078	N
GSA25	1	0	1	N
GSA27	-32	-0.883	0.377	N

A point that requires particular clarification concerns the exclusion of some records of *O. ferox* from Libyan and Syrian waters from the present assessment. According to Shakman *et al*. (2023), the smalltooth sandtiger shark is among the eight elasmobranch species reported as bycatch in the Libyan tuna longline fishery; however, the national inventory of chondrichthyan species occurring off the Libyan coast does not provide precise or even approximate locality data for the captured specimens. Similarly, although two specimens of *O. ferox* have recently been reported from Syrian waters (OBIS, 2024; cited in Pyloridou *et al*., 2025), these records could not be included in the present assessment due to the absence of locality information. Since kernel density estimation (KDE) strictly requires geographic coordinates and weighted numbers of specimens associated with specific localities, records from Libyan and Syrian waters had to be excluded. Nevertheless, it should be noted that, should the locality data of *O. ferox* individuals potentially captured in these regions become available in the future, the existing KDE estimates could be improved by incorporating a broader geographical coverage.

Despite these limitations, when compared with the 14 *O. ferox* individuals reported from the Mediterranean Sea in the compilation by Fergusson *et al*. (2008), the increase to 46 individuals in the present assessment represents an important achievement that is a combined outcome of citizen science, effective use of large datasets, systematic screening of unpublished records, and rigorous taxonomic evaluation. The rapid development of digital technologies, along with the ability to share an observation with the public almost instantaneously and for such information to be noticed and transformed into scientifically valid data by researchers, has gained undeniable momentum. Specifically, SharkPulse, which aims to source large volumes of shark images shared online and transform them into occurrence records (Ferretti *et al*., 2025), represents a revolutionary digital development in this field. However, the increase in *O. ferox* occurrence records facilitated by CS and digital tools should be viewed not merely as an endorsement of these methods, but rather as evidence of their effective application. At the same time, a rigorous screening process must be applied when evaluating shark observation records obtained from social media platforms or citizen science (Mancusi *et al*., 2020). The MEDLEM project, which has been conducted to date to record large cartilaginous fish species throughout the Mediterranean, emphasizes that every new record obtained from these sources must undergo a data quality control process, in which unverified records are removed and duplicate records are eliminated (Mancusi *et al*., 2020). The details of the general algorithm used in the MEDLEM study to generate robust datasets on the distribution of large cartilaginous fish from all data obtained via social media, citizen science, and systematic scientific sampling are provided in full in Mancusi *et al*. (2020).

An examination of the global distribution of *O. ferox* shows that its sporadic records are frequently associated with insular shelves (Ebert *et al*., 2021). Globally, comparable concentrations of records occur only in a limited number of regions, such as the Tasman Sea (Fergusson *et al*., 2008). Topographic features, including seamounts, islands, and the outer margins of continental shelves, appear to be closely associated with the occurrence of *O. ferox* (Ebert *et al*., 2021). A relevant example of such topographic complexity is the Finike Basin and Anaximander Mountain complex, located in the westernmost sector of the northern Levantine Sea (GSA 24) (GFCM, 2018). The major topographic framework of the complex comprises three principal positive morphological features—two ridges and one seamount—situated at the junction of the Hellenic and Cypriot arcs, east of the ~4000 m deep Rhodes Basin (Otero & Mytilineou, 2022). The Anaximander Ridge is an approximately 80 km long, east–west-oriented narrow ridge bounded by steep slopes, rising from depths exceeding 2,000 m to a summit depth of about 1,102 m. The Anaximenes Ridge forms a concave, southwest–northeast oriented structure with a base depth exceeding 1,500 m and a summit depth of 678 m, whereas Anaxagoras Seamount, rising from an over 1,500 m deep seafloor, reaches a summit depth of 919 m (Otero & Mytilineou, 2022). Considering the presence of numerous islands, together with a complex submarine topography characterized by seamounts and ridges, and given that 50% of *O. ferox* records from the eastern Mediterranean originate from this area, the Aegean Sea can be considered one of the few globally important regions for the occurrence of this species. The steadily increasing number of records from the Aegean Sea further supports this interpretation. In addition, records from Mersin, together with those from nearby Cyprus, as well as from Syrian and Lebanese waters to the east, suggest the existence of another potential clustering area in the eastern Mediterranean. Taken together, these findings indicate that the marine region extending from the Aegean Sea to Lebanon may represent a regional hotspot for *O. ferox*, a pattern also supported by the spatial analyses presented in the present study.

In conclusion, *O. ferox* is a species of critical conservation concern in the Mediterranean Sea. Its K-selected life-history traits, including slow growth, late maturity, and low reproductive output, severely limit the capacity of depleted populations to recover rapidly, rendering the species particularly sensitive to additional sources of mortality (Pollard *et al*., 2016). In line with its conservation status, *O. ferox* is legally protected in Türkiye; however, incidental capture as bycatch remains the principal threat to the species throughout the Mediterranean (Carpentieri *et al*., 2021). Although the release of accidentally captured individuals without harm is formally required, such practices are not always implemented effectively in real fishing operations, and mortality associated with handling, delayed release, or inadequate onboard procedures may substantially undermine the intended benefits of legal protection. Under these circumstances, each reliably documented occurrence, particularly those supported by photographic evidence, represents a valuable contribution to understanding the species' distribution and conservation status.

ACKNOWLEDGMENTS

The author thanks the anonymous reviewers for their comments, which helped improve the content and quality of this article.

RAZŠIRJENOST VRSTE *ODONTASPIS FEROX* V SREDOZEMSKEM MORJU: SPOZNANJA NA PODLAGI PROSTORSKIH IN ČASOVNIH ANALIZ

Hakan KABASAKAL
Hydrobiological Research Association (HİDRA), Gökçeada, Çanakkale, Türkiye
e-mail: kabasakal.hakan@gmail.com

POVZETEK

Avtor ponuja posodobljen pregled pojavljanja in razširjenosti morskega psa vrste Odontaspis ferox *v Sredozemskem morju, ki temelji na 46 podatkih iz obdobja med letoma 1964 in 2025. Ugotovil je, da so podatki o pojavljanju neenakomerno porazdeljeni po celotnem bazenu, z izrazito gostoto v Egejskem morju (GSA 22), kjer je zabeležena skoraj polovica vseh zapisov o pojavljanju. Metoda ocene gostote jedra je dodatno potrdila to prostorsko zgostitev in izpostavila vzhodno Sredozemlje. Časovna analiza je razkrila znatno povečanje letnega števila zapisov o pojavljanju, kar odraža tako okrepljena raziskovalna prizadevanja kot tudi vse večji prispevek ljubiteljske znanosti, ki jo omogočajo digitalne tehnologije. Kljub temu da določenih zapisov iz libijskega in sirskega morja zaradi odsotnosti natančnih lokacijskih podatkov ni bilo mogoče zaobjeti, ta zbirka pomeni bistven prirast glede na predhodne ocene.*

Ključne besede: drobnozobi morski vol, razširjenost, vroča točka, ocena gostote jedra, vzhodno Sredozemlje

REFERENCES

Akbora, H.D., E. Bayrı, D. Ayas & B.A. Çiçek (2019): Recent record of *Odontaspis ferox* (Risso, 1810) in Northern Cyprus (Eastern Mediterranean Sea). J. Black Sea/Medit. Environ., 25, 315–320.

Bargnesi, F., S. Gridelli, C. Cerrano & F. Ferretti (2020a): Reconstructing the history of the sand tiger shark (*Carcharias taurus*) in the Mediterranean Sea. Aquatic Conserv. Mar. Freshw. Ecosyst., 30, 915–927. https://doi.org/10.1002/aqc.3301.

Bargnesi, F., S. Lucrezi & F. Ferretti (2020b): Opportunities from citizen science for shark observation, with a focus on the Mediterranenan Sea. Eur. Zool. J., 87, 20–34. https://doi.org/10.1080/24750263.2019.1709574.

Bariche, M. & R. Fricke (2020): The marine ichthyofauna of Lebanon: an annotated checklist, history, biogeography, and conservation status. Zootaxa, 4775, 001–157, https://doi.org/10.11646/zootaxa.4775.1.1

Barone, M., C. Mazzoldi & F. Serena (2022): Sharks, rays and chimaeras in Mediterranean and Black Seas Key to identification. FAO, Rome, 96 pp. https://doi.org/10.4060/cc0830en.

Ben Amor, M.M., M. Bdioui, K. Ounifi-Ben Amor & C. Capapé (2020): Captures of large shark species from the northeastern Tunisian coast (central Mediterranean Sea). Annales, Ser. Hist. Nat., 30, 15–24. https://doi.org/10.19233/ASHN.2020.03.

Bilgili, A. & H. Kabasakal (2023): Encounters with threatened batoids from the perspective of a spearfisherman suggesting an aggregation site in southeastern Aegean Sea, Turkey. Reg. Stud. Mar. Sci., 61, 102894. https://doi.org/10.1016/j.rsma.2023.102894.

Carpentieri, P., A. Nastasi, M. Sessa & A. Srour (eds.) (2021): Incidental catch of vulnerable species in Mediterranean and Black Sea fisheries – A review. Studies and Reviews No. 101 (General Fisheries Commission for the Mediterranean). FAO. Rome, 338 pp. https://doi.org/10.4060/cb5405en.

Coll, M., C. Piroddi, J. Steenbeek, K. Kaschner, F. Ben Rais Lasram, J. Aguzzi, E. Ballesteros, C.N. Bianchi, J. Corbera, T. Dailianis, R. Danovaro, M. Estrada, C. Froglia, B.S. Galil, J.M. Gasol, R. Gertwagen, J. Gil, F. Guilhaumon, K. Kesner-Reyes, M.-S. Kitsos, A. Koukouras, N. Lampadariou, E. Laxamana, C.M. López-Fé de la Cuadra, H.K. Lotze, D. Martin, D. Mouillot, D. Oro, S. Raicevich, J. Rius-Barile, J.I. Saiz-Salinas, C. San Vicente, S. Somot, J. Templado, X. Turon, D. Vafidis, R. Villanueva & E. Voultsiadou (2010): The biodiversity of the Mediterranean Sea: Estimates, patterns, and threats. PLoS ONE, 5, e11842. https://doi.org/10.1371/journal.pone.0011842.

Corsini-Foka, M. (2009): Uncommon fishes from Rhodes and nearby marine region (SE Aegean Sea, Greece). J. Biol. Res. Thessalon., 12, 125–133.

Dulvy, N.K., N. Pacoureau, C.L. Rigby, R.A. Pollom, R.W. Jabado, D.A. Ebert, B. Finucci, C.M. Pollock, J. Cheok, D.H. Derrick, K.B. Herman, C.S. Sherman, W.J. VanderWight, J.M. Lawson, R.H.L. Walls, J.K. Carlson, P. Charvet, K.K. Bineesh, D. Fernando, G.M. Ralph, J.H. Matsushiba, C. Hilton-Taylor, S.V. Fordham & C.A. Simpfendorfer (2021): Overfishing drives over one-third of all sharks and rays toward a global extinction crisis, Curr. Biol., 31, 1–15. https://doi.org/10.1016/j.cub.2021.08.062.

Ebert, D.A., M. Dando & S. Fowler (2021): Sharks of the World: A Complete Guide. Princeton University Press, Princeton, 608 pp.

Fergusson, I.K., K.J. Graham & L.J.V. Compagno (2008): Distribution, abundance and biology of the smalltooth sandtiger shark *Odontaspis ferox* (Risso, 1810) (Lamniformes: Odontaspididae). Environ. Biol. Fish., 81, 207–228. https://doi.org/10.1007/s10641-007-9193-x.

Geldiay, R. (1969): İzmir Körfezinin Başlıca Balıkları ve Muhtemel İnvasionları. İzmir: Ege Üniversitesi Matbaası.

Gibson, K.J, M.K. Streich, T.S. Topping & G.W. Stunz (2019): Utility of citizen science data: A case study in land-based shark fishing. PLoS ONE, 14, e0226782. https://doi.org/10.1371/journal.pone.0226782.

Hammer, Ø., D.A.T. Harper & D.R. Paul (2001): Past: Paleontological Statistics Software Package for Education and Data Analysis. Palaeont. Electr., 4(1), 9. http://palaeo-electronica.org/2001_1/past/issue1_01.htm.

Heupel, M.R. & C.A. Simpfendorfer (2010): Science or slaughter: need for lethal sampling of sharks. Conserv. Biol., 24, 1212–1218. doi: 10.1111/j.1523-1739.2010.01491.x.

Kabasakal, H. (2009): Observations on a rare shark, *Oxynotus centrina* (Chondrichthyes: Oxynotidae), in the Sea of Marmara (north-western Turkey). Pan-american J. Aquat. Sci., 4, 609–612.

Kabasakal, H. & E. Bayrı (2019): Notes on the occurrence of smalltooth sandtiger shark, *Odontaspis ferox* (Lamniformes: Odontaspididae) from Antalya Bay, eastern Mediterranean, Turkey. J. Black Sea/Mediterr. Environ., 25, 166–171.

Kabasakal, H. & M. Bilecenoğlu (2020): Shark infested internet: an analysis of internet-based media reports on rare and large sharks of Turkey. FishTaxa 16, 8–18.

Kabasakal, H., M. Bilecenoğlu & E. Bayrı (2024): Historical and contemporary occurrence of *Odontaspis ferox* (Risso, 1810) (Lamniformes: Odontaspididae) in Turkish Seas, with additional records from the region. Turk. J. Biosci. Collect., 8(1), 9–15. https://doi.org/10.26650/tjbc.1345982.

Mancusi, C., R. Baino, C. Fortuna, L. de Sola, G. Morey, M. Bradai, A. Kallianotis, A. Soldo, F. Hemida, A. Saad, M. Dimech, P. Peristeraki, M. Bariche, S. Clo, E. de Sabata, L. Castellano, F. Garibaldi, L. Lanteri, F. Tinti, A. Pais, E. Sperone, P. Micarelli, F. Poisson, L. Sion, R. Carlucci, D. Cebrian-Menchero, B. Séret, F. Ferretti, A. El-Far, I. Saygu, E. Shakman, A. Bartoli, J. Guallart, D. Damalas, P. Megalofonou, M. Vacchi, M. Bottaro, G. N. di Sciara, M. Follesa, R. Cannas, H. Kabasakal, B. Zava, G. Cavlan, A. Jung, M. Abudaya, J. Kolitari, A. Barash, A. Joksimovic, B. Marceta, L. Gonzales Vilas, F. Tiralongo, I. Giovos, F. Bargnesi, S. Lelli, M. Barone, S. Moro, C. Mazzoldi, C. Charis, A. Abella & F. Serena (2020): MEDLEM database, a data collection on large elasmobranchs in the Mediterranean and Black seas. Mediterr. Mar. Sci, 21, 276–288.

Mazzoldi, C., G. Bearzi, C. Brito, I. Carvalho, E. Desiderà, L. Endrizzi, L. Freitas, E. Giacomello, I. Giovos, P. Guidetti, A. Ressurreição, M. Tull & A. MacDiarmid (2019): From sea monsters to charismatic megafauna: Changes in perception and use of large marine animals. PLoS ONE, 14, e0226810. https://doi.org/10.1371/journal.pone.0226810.

Moutopoulos, D.K., E. Lazari, G. Katselis & I. Giovos (2022): From extermination to conservation: Historical records of shark presence during the early and development phase of the Greek fishery. Animals, 12, 3575. https://doi.org/10.3390/ani12243575.

OBIS (2024): Ocean Biodiversity Information System. Intergovernmental Oceanographic Commission of UNESCO. Available from https://obis.org.

Otero, M. & C. Mytilineou (eds.). (2022): Deep-sea Atlas of the Eastern Mediterranean Sea. IUCN-HCMR DeepEastMed Project. Publisher, IUCN Gland, Malaga. (VII+371 pp.).

Page, M.J., J.E. McKenzie, P.M. Bossuyt, I. Boutron, T.C. Hoffmann, C.D. Mulrow, L. Shamseer, J.M. Tetzlaff, E.A. Akl, S.E. Brennan, R. Chou, J. Glanville, J.M. Grimshaw, A. Hróbjartsson, M.M. Lalu, T. Li, E.W. Loder, E. Mayo-Wilson, S. McDonald, L.A. McGuinness, L.A. Stewart, J. Thomas, A.C. Tricco, V.A. Welch, P. Whiting & D. Moher (2021): The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71.

Parab, S. & S. Bhalerao (2010): Choosing statistical test. IJAR., 1, 187–191. https://doi.org/10.4103/0974-7788.72494.

Pollard, D.A., I. Gordon, S. Williams, A.A. Flaherty, I. Fergusson, M. Dicken & K.J. Graham (2016): *Odontaspis ferox* (Mediterranean assessment). The IUCN Red List of Threatened Species 2016: e.T41876A16527837. Accessed on 11 March 2026.

Pyloridou, K., I. Athinaiou, M. Ciprian, R.N. Aga-Spyridopoulou & I. Giovos (2025): New insights in the distribution of the smalltooth sandtiger (*Odontaspis ferox* (Risso, 1810)) in the Mediterranean. Reg. Stud. Mar. Sci., 91, 104596. https://doi.org/10.1016/j.rsma.2025.104596.

Serena, F. & A. Soldo (2024): Mediterranean and Black Seas. Chapter 7 | Mediterranean and Black seas. In: Jabado, R.W., Morata, A.Z.A., Bennett, R.H., Finucci, B., Ellis, J.R., Fowler, S.L., Grant, M.I., Barbosa Martins, A.P., & Sinclair, S.L. (eds.): The global status of sharks, rays, and chimaeras. IUCN, Gland, 753753-760–760. DOI: https://doi.org/10.59216/ssg.gsrsrc.2024. ISBN: 978-2-8317-2318-1.

Shakman, E., A. Siafenasar, K. Etayeb, A. Shefern, A. Elmgwashi, M. Al Hajaji, N.B. Benghazi, A. Ben Abdalha, M. Aissi & F. Serena (2023): National inventory and status of chondrichthyes in the South Mediterranean Sea (Libyan Coast). Biodivers. J., 14, 459–480. https://doi.org/10.31396/Biodiv.Jour.2023.14.3.459.480.

Silverman, B.W. (1986): Density estimation for statistics and data analysis. Chapman & Hall, London, 22 pp.

Soldo, A. (2026): When citizen science becomes speculation: Evaluating the reliability of lamnid shark identification from photographic records in the Mediterranean. J. Mar. Sci. Eng., 14, 173. https://doi.org/10.3390/jmse14020173.

Soldo, A., R. Bakiu & N. Hysolakoj (2022): New record of smalltooth sand tiger *Odontaspis ferox* (Risso, 1810) in the Mediterranean. J. Mar. Biol. Assoc. U.K., 102, 502–504. https://doi.org/10.1017/S0025315422000819.

Tiralongo, F., G. Torre & A. De Maddalena (2025): Trophic interactions between the giant devil ray *Mobula mobular* and sharks in Sicilian waters (Mediterranean Sea). Mar. Biol. J., 10, 102–105. https://marine-biology.ru/mbj/article/view/500.

Walker, T.I. (1998): Can shark resources be harvested sustainably? A question revisited with a review, of shark fisheries. Mar. Freshwater Res., 49, 553–572. https://doi.org/10.1071/MF98017.

Warton, D.I. (ed.) (2022): Eco-Stats: Data Analysis in Ecology: From t-tests to Multivariate Abundances. Springer Nature, Cham, 433 p.

WoRMS Editorial Board (2026): World Register of Marine Species. Available from https://www.marinespecies.org at VLIZ. Accessed on 18 January 2026. https://doi.org/10.14284/170.

Zaferiaki, E., W.A. Gebbink, S.P.J. van Leeuwen, E. Dassenakis & P. Megalofonou (2019): Occurrence and tissue distribution of perfluoroalkyl substances (PFASs) in sharks and rays from the eastern Mediterranean Sea. Environ Pollut., 252, 379–387. https://doi.org/10.1016/j.envpol.2019.05.120.