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Range expansion or residency? First record of a potentially stable population of *Dentex maroccanus* in the central Adriatic Sea

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Abstract

Updating knowledge about the distribution ranges and population parameters of fish species is essential for effective management of fish resources and for understanding how Mediterranean fauna are adapting to ongoing warming trends. The Morocco dentex (*Dentex maroccanus*) is a sparid species typically found in the southern Mediterranean Sea; however, there is currently a dearth of records from the northern sector of the basin. Here, we present the initial evidence of a potentially stable and resident population of *D. maroccanus* in the Adriatic Sea, the northernmost Mediterranean basin. A total of 47 individuals were collected from commercial trawling and recreational catches on muddy bottoms at depths of 60–80 m between February and May 2025. Species identification was validated using meristic traits and otolith morphology. The sampled individuals ranged from 6.7 to 22.5 cm in total length, and the length–weight analysis indicated isometric growth ($t = -1.05$, $p = 0.29$). Macroscopic gonad examination indicated that individuals caught in spring were approaching the spawning season, which typically occurs during the warm months. Males were found in maturing and ripening stages, while females were only immature or maturing. The occurrence of both small and large individuals over relatively wide temporal and spatial scales, together with evidence of reproductive investment, supports the hypothesis that the specimens belong to a locally established population rather than being isolated occurrences. The observed size distribution and sexual differences in relation to the various fishing techniques suggest possible behavioral and ecological factors influencing capture selectivity. The documented warming trend of the Adriatic Sea, along with its status as a hotspot for the expansion of thermophilic species, suggests that our findings likely indicate an ongoing northward range shift of *D. maroccanus*.

Keywords: Sparidae; Morocco dentex; Adriatic Sea; thermophilic species; distribution area.

Introduction

Dentex maroccanus Valenciennes, 1830 (Morocco dentex) is a demersal sparid inhabiting sandy, gravelly, or muddy bottoms at depths ranging from 20 to 500 m, feeding primarily on crustaceans, molluscs, and fishes (Mina *et al.*, 2023). Its main distribution extends from the eastern Atlantic to the Mediterranean Sea, where it is more commonly recorded in the southern basin. In contrast, records from the northern and central sectors have historically been rare (Psomadakis *et al.*, 2012). In the Aegean and Levantine Seas, *D. maroccanus* is considered relatively frequent, and recent studies on age, growth, and otolith morphology have suggested that this species can adapt its life-history traits to local environmental conditions, supporting its persistence across diverse habitats (Mina *et al.*, 2023; Legaki *et al.*, 2024).

In recent decades, the Mediterranean Sea has been undergoing a marked process of warming, often referred to as "tropicalization," which has been linked to the northward expansion of thermophilic species and the establishment of non-indigenous taxa (Bianchi & Morri, 2003; Azzurro *et al.*, 2012). Increasing sea surface temperatures, together with changes in salinity and hydrographic circulation, have reshaped the distributional ranges of numerous native fishes and facilitated the colonization of new areas by thermophilic species (Shaltout & Omstedt, 2014; Garrabou *et al.*, 2022).

The Adriatic Sea represents a particularly intriguing case study within this broader context. It is a semi-enclosed sub-basin with pronounced latitudinal gradients: the shallow, river-influenced Northern Adriatic; the deeper and warmer central sector; and the Southern Adriatic Pit with its cyclonic circulation and dense-water forma-

tion (Russo & Artegiani, 1996; Cushman-Roisin *et al.*, 2001). Such hydrographic and ecological heterogeneity, combined with ongoing warming trends (Lipizer *et al.*, 2014), creates a complex but potentially favorable environment for thermophilic species.

These conditions, together with the presence of heterogeneous substrates and rich prey fields, suggest that the central Adriatic Sea could provide a suitable habitat for *D. maroccanus*. More broadly, they highlight this basin's potential to host not only native thermophilic sparids but also invasive species able to exploit the ongoing climatic and oceanographic changes in the Mediterranean Sea.

This study aims to present the first record of a potentially stable and resident population of *D. maroccanus* in the central Adriatic Sea by examining key biological traits, such as reproduction and growth type, which may provide evidence for its local establishment. By providing baseline information on the occurrence and biology of *D. maroccanus* in this region, this study enhances our understanding of how ongoing climatic changes are reshaping Mediterranean fish communities. Additionally, it supports the development of adaptive management strategies for regional fisheries.

Materials and Methods

Morocco dentex individuals were identified and collected opportunistically from fishing activities conducted in the offshore waters of the central Adriatic Sea between February and May 2025, at depths ranging from 60 and 80 m (Fig. 1), on muddy bottoms. The species was identified following the criteria described by Bauchot & Hureau (1986). Specifically, the diagnostic features for this species include the number of gill rakers on the first branchial arch (9–12 on the lower limb) and equally developed canines in the upper and lower jaws. Moreover, the species identification was further validated through the otolith morphology, using the AFORO database (Lombarte *et al.*, 2006).

Out of 47 individuals, 35 were captured and sorted from the discarded fractions during commercial trawling operations conducted in March, April, and May. These operations were performed by bottom trawlers from the Ancona fishing fleet, utilizing the typical commercial bottom trawl nets known locally as 'Americana' (Petetta *et al.*, 2022). Sampling activities were carried out within the National Plan of Recovery and Resilience (PNRR) and the EU Data Collection Framework by scientific personnel of the Institute for Marine Biological Resources and Biotechnology of the National Research Council (CNR-IRBIM). Twelve individuals were from the recreational fishery (February and April), employing fishing rods baited with squid strips and size 4 Mustad J-hooks (Table 1).

Total length (TL) to the nearest mm, total weight (TW) to the nearest 0.1 g, and gonad weight (GW) to the nearest 0.01 g were recorded for each specimen. The sagittal otoliths were removed, cleaned, and observed with a stereomicroscope under reflected light with a dark background for identification purposes. Sex was assigned macroscopically using the five-point scale for partial spawners (Holden & Raitt, 1974): 1) Immature; 2) Maturing and recovering spent; 3) Ripening; 4) Ripe; 5) Spent. The gonadosomatic index (GSI = GW/TW × 100) was calculated to evaluate the reproductive investment in gonads (Taylan *et al.*, 2018).

The length-weight (LW) relationship was assessed by fitting the equation:

$$W = \alpha \times TL^{b}$$

where W represents body weight (g), TL is total length (cm), and *a* and *b* are the model parameters, with *b* in-

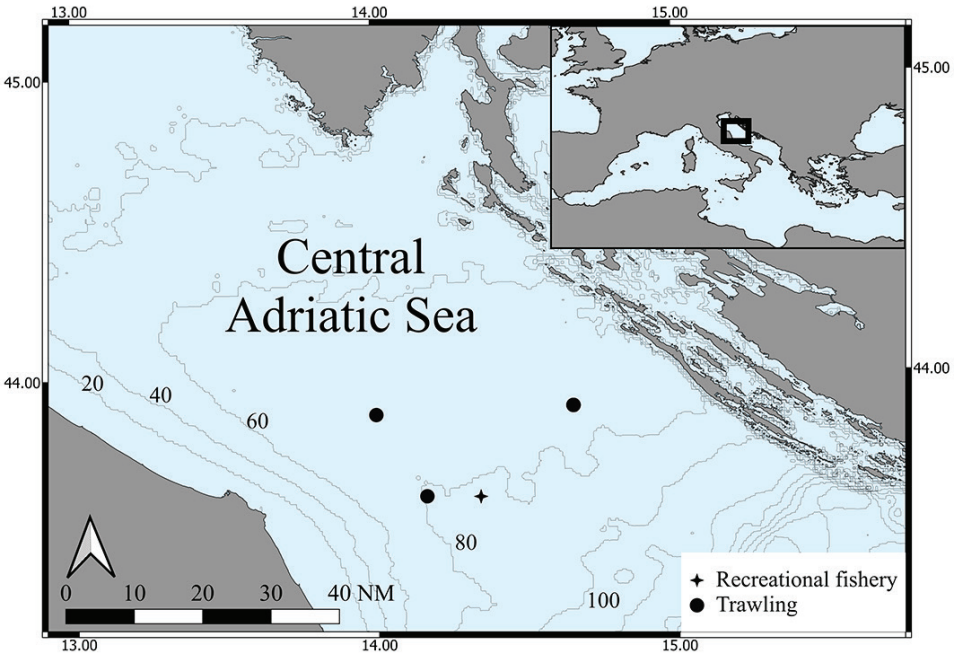

Fig. 1: Locations of Morocco dentex records from trawling (circles) and recreational fisheries (cross) in the central Adriatic Sea.

Table 1. Number of individuals (N), dates, and locations of *Dentex maroccanus* caught in the central Adriatic Sea.

Sampling	Date	Coordinates	N
Recreational fishery 1	11/02/2025	43.5965°N 14.3455°E	1
Commercial trawling 1	20/03/2025	43.873°N 14.0013°E	1
Commercial trawling 2	10/04/2025	43.6000°N 14.1666°E	1
Recreational fishery 2	23/04/2025	43.5965°N 14.3455°E	11
Commercial trawling 3	12/05/2025	43.7606°N 14.2610°E	33

dicating the allometric growth coefficient. A Student's t-test was performed to evaluate the growth pattern based on the *b* value, where $b = 3$ indicates isometric growth (Sokal & Rohlf, 1995). Differences in length-frequency distributions (LFD) between sexes and sampling types were compared using the non-parametric Kolmogorov-Smirnov test (significance level of 0.01).

Results

The criteria used to identify the samples as individuals of *D. maroccanus* corresponded with the species' diagnostic features and previous records in the literature (Fig. 2). The size of Morocco dentex samples ranged from 6.7 to 22.5 cm TL. The range for female individuals was from 10.6 to 15.9 cm TL, whereas for male individuals it was from 10.5 to 20.7 cm TL. In four specimens (comprising the smaller and larger individuals), the sex could not be determined macroscopically due to their small size and/or the gutting operations performed by recreational fishers.

Macroscopic examination of gonads was performed on individuals caught in April and May, revealing evidence of spawning activity, particularly among male specimens. While males were found in immature, maturing, and ripening stages, females were only found in immature and maturing stages (Table S1). The smallest male with mature gonads measured 13.2 cm TL (ripening stage), while no females in advanced maturity stages were found. In females, GSI values (mean ± SD) ranged from 1.01 ± 0.35 in the immature stage to 1.50 ± 0.35 in the maturing stage. Males exhibited overall lower GSI values, ranging from 0.23 in the immature stage to 0.26 ± 0.13 in the maturing stage and reaching 0.51 ± 0.18 in the ripening stage.

The LW relationship is described by the equation $W = 0.0175 \times TL^{2.936}$ (Figure S1). Somatic growth, measured by the allometric index (b), did not differ significantly from 3, indicating isometric growth (t-test, t = -1.05, p

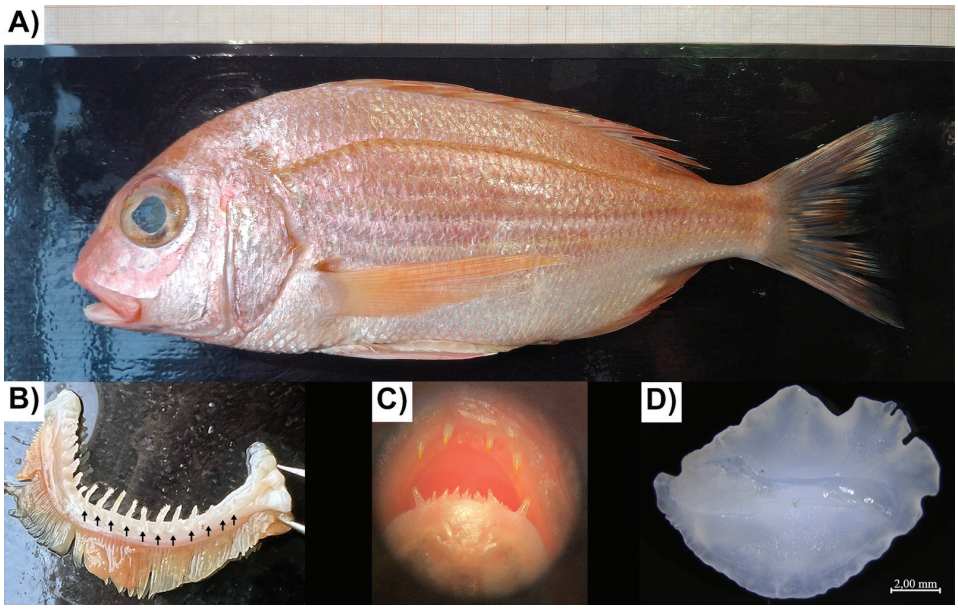

Fig. 2: An individual of *Dentex maroccanus* measuring 22.5 cm TL (A) alongside anatomical features used for species identification validation, B) the first branchial arch, with arrows indicating the location of the lower gillrakers, C) a detailed view of the upper and lower jaws, showing well-developed canines on both sides, and D) the right otolith displaying the sulcus acusticus on the proximal side.

= 0.29). There were significant differences in LFDs between males and females (D = 0.63, p < 0.01), with males exhibiting a larger size than females (Fig. 3A). Individuals originating from recreational fishing were larger in size than those from trawling (D = 0.72; p > 0.01; Figure 3B).

Discussion

The data presented in this paper confirm, for the first time, the presence of *D. maroccanus* in the Adriatic Sea. This finding updates this species' distribution area, which was previously known only in the eastern and southern parts of the Mediterranean Sea. A solitary specimen of this species was recently reported in the transition area between the Northeastern Ionian Sea and the Southern Adriatic Sea (Grech *et al.*, 2023), probably signifying an early indication of its expanding distribution range. Moreover, the capture of several individuals over four months, covering a broad size range, and exhibiting evidence of spawning activity, suggests that the sampled individuals may be part of a population in a growing phase, never before reported in the area.

The size range of the present sample overlaps with observations from previous studies carried out in the Mediterranean Sea (Mohdeb & Cara, 2015; Heral & Bayhan, 2020; Legaki *et al.*, 2024), despite the latter having significantly larger sample sizes. Consequently, even with the limited number of individuals, the sample analyzed in the present study can be considered representative of the species' size range. The larger individuals in our sample originated from recreational fisheries and were predominantly males (except for one unsexed individual), suggesting sex-related size differences. Although Mohdeb & Cara (2013) reported sexual dimorphism in this species, it pertains solely to morphological traits; growth and maximum size do not differ between the sexes (Mohdeb & Cara, 2015; Legaki *et al.*, 2024). A potential explanation for the high proportion of large male specimens caught through recreational fisheries could be related to the specific fishing technique and behavioral differences between sexes. In fact, in some fish species, males may be more aggressive, exhibiting territorial behaviors that may lead them to approach lures earlier than females (Cooke *et al.*, 2000), thereby increasing their probability of capture. In addition, the larger size of individuals from recreational fisheries, in contrast to those from trawling, may be attributed to lower fishing pressure in recreational fishing spots, which frequently feature irregular seabeds that hinder bottom trawling due to potential damage to the gear from rocks or wrecks (Hickman *et al.*, 2024). Ultimately, hook size may also have influenced the size disparity in sampling, as it is the principal factor determining selectivity in rod fishing (Alós *et al.*, 2008).

The limited number of individuals and the difference

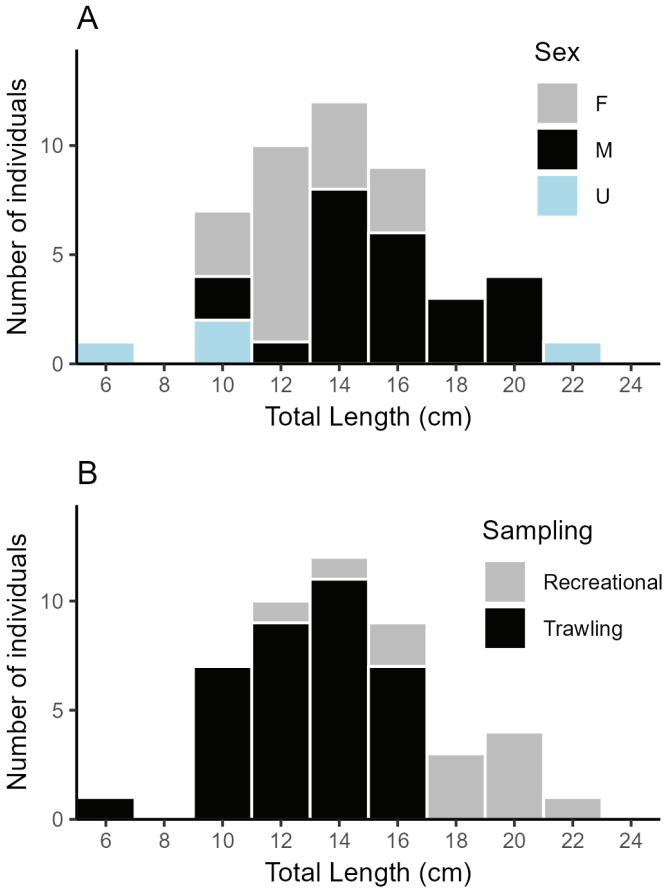

Fig. 3: Length-frequency distributions of *Dentex maroccanus* caught in the central Adriatic Sea by sex (A) and sampling type (B). F = females; M = males; U = undetermined sex.

in mean body size between sexes prevented us from calculating a sex-specific LW relationship, even though previous studies have reported no significant difference in the b parameter (Mohdeb & Cara, 2015; Legaki *et al.*, 2024). The calculated b value was consistent with the isometric growth pattern identified by Legaki *et al.* (2024); however, it differed from findings in other studies (Gul *et al.*, 2014; Mohbed and Cara, 2015; Heral & Bayhan, 2020). While a larger sample size may have improved the accuracy of the estimation, variations in the parameter b of the LW relationship can be attributed to factors such as sampling location, collection season, the species' life-history stage, or the body condition of the individuals (Ricker, 1975). Additionally, these differences may be linked to the use of total vs. eviscerated weight (Legaki *et al.*, 2024).

Macroscopic examination of gonads, carried out in April and May, revealed differences between the sexes. Males were observed with maturing or mature gonads, while females were found to be immature or in maturing stages. Consequently, one may infer that the individuals collected were at the beginning of the spawning phase. This result is consistent with other observations in the Mediterranean Sea, with reports of an extended spawning period from May to September (Gul *et al.*, 2014; Mohdeb & Cara, 2015; Taylan *et al.*, 2018). The observation that males showed more advanced maturity stages than females could be related to their larger size in the analyzed sample (as discussed above) and to differences in size at maturity. Since the length at first maturity has been estimated at 13 cm TL for males and 15.8 cm TL for females (Gul *et al.*, 2014), the absence of mature females in our sample is likely attributable to the relatively small size of the female specimens collected.

Although this study's small sample size did not permit a proper estimation of age and growth parameters, the presence of both small and large individuals (close to the maximum size of 26.8 cm TL reported for the Mediterranean area by Mohdeb & Cara, 2015) supports the hypothesis that these individuals probably belong to an already established population in the study area. Considering that the lifespan of this species ranges between 5 and 8 years (Mohdeb & Cara, 2015; Heral & Bayhan, 2020; Legaki *et al.*, 2024), it is worth mentioning that the expansion of the species in the study area has not been systematically documented in previous research, which presents a significant limitation in our understanding of the process. Given that juvenile sparids (with a TL < 16 cm) are abundant in commercial catches (Fig. 3B), they are often discarded without being properly sorted from other mixed species. This practice makes their presence and observation difficult to detect and document. Consequently, it is plausible that the species' expansion occurred earlier than reported in the literature; yet, due to the above-mentioned reasons, one cannot dismiss the possibility of misidentification with other sparid species. A second plausible explanation could be the scenario of a rapid expansion of the species in the Adriatic Sea, triggered by rising sea temperatures. Although satellite data confirm that the entire Mediterranean Sea has undergone a warming process over the last 20 years, the Adriatic Sea has been recognized as the basin with the highest warming trend (García-Monteiro *et al.*, 2022). This renders it a favorable area for the expansion of thermophilic species from the southern Mediterranean Sea, including the Morocco dentex. Therefore, it can be tentatively hypothesized that the exceedance of a specific temperature threshold caused a substantial increase in larval survival and/or habitat suitability for the species, leading to the rapid colonization of a new area.

Both explanations may be equally valid: the northward spread of the Morocco dentex may have occurred over an extended period, while challenges in identifying the species could have hindered the detection of its expansion in the Adriatic Sea. Over the past 15 years, several thermophilic species have been reported for the first time in the Adriatic Sea (Lipej *et al.*, 2022). This case may represent yet another example of how rising temperatures are causing shifts in the typical fauna of different Mediterranean regions. Taking into account the biological aspects along with the spatial and temporal scales of the records, it can be argued that the individuals collected may belong to a well-established population. The occurrence of both small and large specimens, signals of reproductive activity, and repeated captures over a few months of opportunistic observations provide support for the hypothesis that *D. maroccanus* is probably already settled in the Adriatic Sea. The present findings highlight the importance of improving continuous monitoring and taxonomic resolution in fisheries data, as well as the need to assess the ecological and fisheries implications of this new component within Adriatic fish assemblages. Future research should focus on long-term monitoring, genetic analyses, and reproductive and trophic studies to confirm population identity and clarify the ecological role of this species within the Adriatic ecosystem.

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Supplementary Data

The following supplementary information is available online for the article:

Table S1. Mean and Standard Deviation of Gonadosomatic Index (GSI) values for Morocco dentex individuals by sex and macroscopic maturity stage. N = number of individuals.

Fig. S1: Length-weight relationship for Morocco dentex individuals caught in the central Adriatic Sea (N = 47).