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The presence of the non-native diamond lizardfish *Synodus synodus* off the coast of Benghazi, Libya: Implications for Mediterranean biodiversity

by

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Abstract

As one of the world's foremost hotspots for marine bioinvasions, the Mediterranean Sea functions as a dynamic theater where both introduced aliens and naturally range-expanding neonative species are actively rewriting the region's biodiversity narrative. Among the fishes navigating this shifting landscape, the diamond lizardfish *Synodus synodus*, a species of subtropical Atlantic origin, has historically remained on the periphery of the basin's ichthyofauna, its presence long regarded as incidental and supported by little more than fragmentary or poorly substantiated records. The present study confirms the occurrence of *S. synodus* (Linnaeus, 1758) along the central southern coast of the Mediterranean, based on morphological examination of three specimens collected on 18 June 2025, off the coast of Benghazi, Libya. Meristic counts and morphometric measurements yielded diagnostic characters unequivocally consistent with the species. The confirmation of *S. synodus* in Libyan waters carries considerable ecological and zoogeographical weight, particularly when viewed against the broader backdrop of the species' progressive range expansion throughout the Mediterranean Basin.

Key words: non-indigenous species, coastal ecosystems, neonative species, species establishment, uncommon species, morphological identification

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1. Introduction

In the Mediterranean Sea, the family Synodontidae is represented by a mix of native and non-indigenous species. The native ichthyofauna includes *Synodus saurus* (Linnaeus, 1758) and the possibly neonative [*sensu* Essl et al., 2019] *S. synodus* (Linnaeus, 1758) (see Kovačić et al., 2021). Additionally, three non-indigenous species of Indo-Pacific/Red Sea origin have been recorded: *Saurida lessepsianus* Russell, Golani et Tikochinski, 2015 (see Russell et al., 2015), *Saurida gracilis* (Quoy et Gaimard, 1824) (see Khamassi et al., 2022), and *Synodus randalli* Cressey, 1981 (see Langeneck et al., 2023). Among these, the Atlantic lizardfish *S. saurus* is widely distributed throughout the basin, whereas the diamond lizardfish, *S. synodus*, exhibits a scattered and poorly documented presence.

S. synodus is a subtropical species native to both the eastern and western Atlantic. Although it was first reported in the Mediterranean by Anderson et al. (1966a), the same authors (Anderson et al., 1966b) subsequently excluded the basin from its distribution range. For decades, the species was not included in regional fish checklists (cf. Bauchot, 1987; Froese & Pauly, 2025; Psomadakis et al., 2012; Quignard & Tomasini, 2000; Sulak, 1984), until it was recently added by Kovačić et al. (2021) based on four photographs from Bello Rincon, Almería (Spain) published in Lloris (2015). Its distribution in the Mediterranean appears uneven, with no records in most national checklists, except for Egyptian Mediterranean waters (Akel & Karachle, 2017).

The diamond lizardfish *S. synodus* was recently confirmed in Maltese waters, constituting the first genetically verified record in the central Mediterranean Sea (Deidun et al., 2025). Di Franco et al. (2026) reported this species from the Cyclades, Crete (Greece) and Linosa Island (Italy), Farhat et al. (2026) from the coastal waters of Lebanon, and Zenetos et al. (2026) from Latakia, Syria.

Within this context, the family Synodontidae presents a compelling case study. The genus *Synodus* (Scopoli, 1777) comprises 49 species distributed across tropical and subtropical regions of the Atlantic, Pacific, and Indian Oceans (Fricke et al., 2025; Froese and Pauly, 2025). These benthic fishes inhabit sandy, rocky, seagrass, and coral reef substrates, occurring at depths exceeding 400 m and are predominantly piscivorous (Erguden et al., 2024; Froese & Pauly, 2025).

Recent studies from the Mediterranean Sea provide evidence of the native *S. saurus* (Linnaeus, 1758) coexisting with two congeners of distinct origins. *S. randalli* (Cressey, 1981), native to the Red Sea and the western Indian Ocean (Fricke et al., 2025), likely entered the Mediterranean via the Suez Canal. Since 2023, it has been recorded in Mersin Bay (Türkiye) and off the coast of Crete (Greece), where a reproducing population is suspected (Christidis & Kosoglou 2024; Erguden et al., 2024; Langeneck et al., 2023; but, see Bariche et al. (2025) and Deidun et al. (2025) for a discussion on the potential misidentification of this species in the Mediterranean Sea.

In the present study, the occurrence of *S. synodus* in Libyan waters, along the southern coasts of the Mediterranean Sea, is documented for the first time. This record is based on three specimens collected from the coast of Benghazi City, Libya. Species identification was confirmed through a detailed analysis of morphometric and meristic characters.

The presence of *S. synodus* in Libyan waters holds significant biogeographic and ecological importance. It fills a substantial gap in the known distribution of the species within the central-southern Mediterranean and suggests that its occurrence may be more continuous than previously assumed. This finding highlights the need for revised regional checklists and underscores the value of local surveys in uncovering hidden biodiversity. Moreover, it contributes to a better understanding of the shifting distribution patterns of both native and neonative species in the Mediterranean, a region highly susceptible to environmental change and biological invasions.

2. Materials and methods

On 18 June 2025, three specimens of *S. synodus* were captured by artisanal fishermen using a trammel net off the coast of Benghazi, Libya, in the southern Mediterranean Sea (32.06°N, 20.03°E) (Fig. 1). The specimens were collected at a depth of approximately 20 m over a sandy substrate, together with individuals of *S. saurus*. Following capture, the specimens were immediately placed on ice and transported to the Department of Zoology, Faculty of Science, University of Benghazi, for further examination. They were subsequently preserved in 90% ethanol to facilitate future analyses. Species identification was carried out based on morphological characters following Anderson et al. (1966a,b) and Deidun et al. (2025). Morphometric measurements were taken to the nearest 0.1 mm using a digital caliper, while meristic counts were performed under a stereomicroscope (Leica EZ4, Singapore) in accordance with Hubbs and Lagler (1958). The three voucher specimens are currently deposited in the collections of the Department of Zoology, Faculty of Science, University of Benghazi.

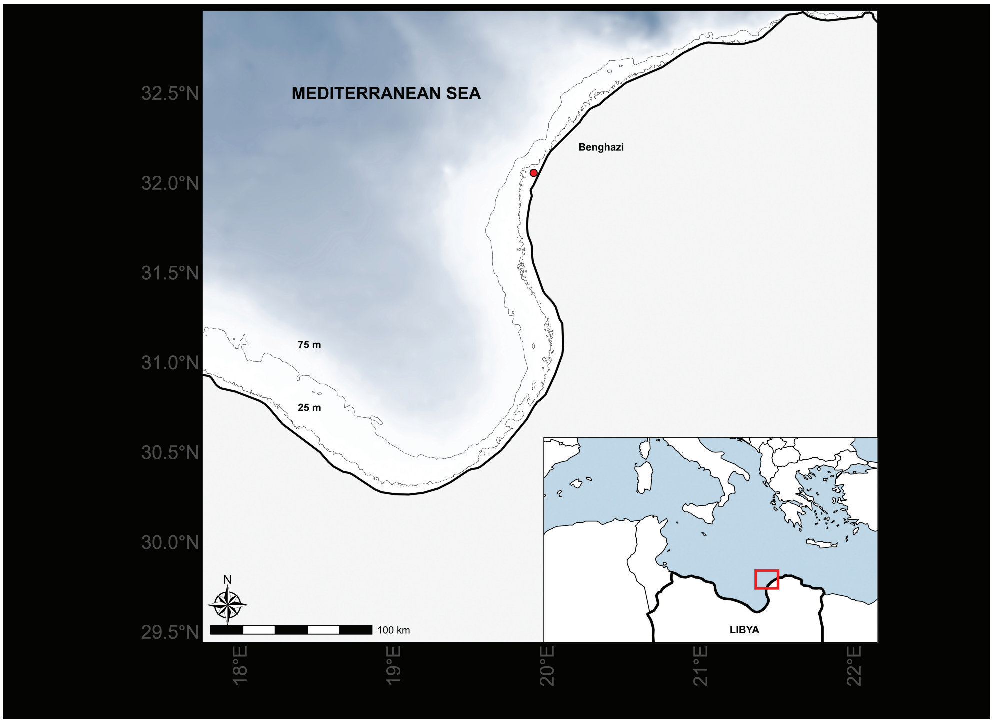

Figure 1

Capture location of *S. synodus* off the coast of Benghazi, Libya. The red square indicates the locality of fish collection.

3. Results

The three specimens of *S. synodus* collected from Libyan waters measured 194, 230, and 233 mm in total length; 190, 212, and 215 mm in fork length; and 176, 204, and 205 mm in standard length (SL) (Fig. 2). A comparative overview of their morphometric and meristic characteristics alongside specimens from other localities is provided in Table 1.

Morphological description: Body elongated and cylindrical. First dorsal fin with a short base; second dorsal fin small and adipose. Anal fin base shorter than dorsal fin base. Caudal fin forked; lateral line extends to the base of the caudal fin. Snout rounded in dorsal view, pointed laterally. Eye positioned approximately at the midpoint of the upper jaw. Innermost rays of pelvic fins longer than the outermost. Pectoral fin does not reach the imaginary line connecting the origins of the pelvic and dorsal fins and is less than half the length of the pelvic fin. Cheek fully covered with scales arranged in five rows. Jaws armed with lanceolate teeth arranged in alternating long and short series. Mouth oblique. On each side of the palate, a single band of lanceolate palatine teeth is arranged in multiple rows; teeth in the inner rows are longer, with the anterior ones being the largest (Figs 3A and 3B). Lingual teeth well developed; those on the free end of the tongue are the largest, numbering approximately 48 in specimen A (Fig. 3A). The anterior nostril on each side bears a long flap that, when depressed anteriorly, extends well beyond the margin of the nares (Fig. 3C).

Coloration: Four large reddish-brown bands traverse the back between the dorsal fin origin and the base of the caudal fin, alternating with orange bands. Sparse sky blue shades are present on the body. A prominent black spot adorns the upper surface of the snout tip (Fig. 3D). Four reddish-brown large bands across the back between the dorsal origin and caudal fin base alternated with orange bands; sparse sky blue shades; black spot on the upper surface of the tip of the snout.

The morphometric and meristic data for the three *S. synodus* specimens collected off the coast of Benghazi, Libya, are presented in Table 1. The specimens ranged from 176 to 205 mm in SL and weighed between 71.7 g and 114.9 g. Morphometric proportions relative to SL were generally consistent across individuals. Head length constituted 24.87%–26.70% SL, while snout length ranged from 4.39% to 4.90% SL. Upper jaw length measured 16.09–17.04% SL, and the diameter of the bony orbit varied between 3.40% and 4.90% SL. Pre-dorsal, pre-pelvic, and preanal fin origins were positioned at 40.00%–41.66% SL, 30.88%–34.63% SL, and

Figure 2

S. synodus specimen (194 mm TL) collected off the coast of Benghazi, Libya, in the southern Mediterranean Sea. Photograph by H. Elbaraasi. TL, total length.

Table 1

Morphometric and meristic characteristics of *S. synodus* collected from the Libyan waters of the Mediterranean Sea off the city of Benghazi, compared with results obtained from various localities.

	This study *n* = 3	Deidun et al. (2025) *n* = 2	Di Franco et al. (2026) *n* = 1	Farhat et al. (2026) *n* = 2
Weight (g)	71.7–114.2	38.6, 244.7	221	27.5, 34.0
Morphometric characters (mm)				
Total length	194–233	166.1, 300.2	265	160, 168
Fork length	190–215 (93.5%–97.9%)	154.2 (92.8%), 277.3 (90.3%)	-	150 (93.5%), 160 (95.2%)
SL	176–205 (87.9%–90.7%)	146.1 (88%), 260 (86.6%)	238	142 (88.8%), 149 (88.7%)
Head length	47–51 (24.87%–26.70%)	35.5 (24.2%), 62.8 (24.3%)	-	31.6 (22.3%), 38.3 (25.7%)
Snout length	8–10 (4.39%–4.9%)	6.0 (3.8%), 10.0 (4.1%)	-	8.3 (5.9%), 8.6 (5.8%)
Upper jaw length	30–33 (16.09%–17%)	24.2 (16.6%), 46.3 (17.8%)	-	23.7 (16.7%), 26.3 (17.7%)
Eye diameter	6–10 (3.40%–4.9%)	12.0 (4.6%), 7.0 (4.8%)	-	7.1 (5%), 7.2 (4.8%%)
Least width of the bony Interorbital	4–6 (2.3%–2.9%)	4.2 (2.9%), 8.3 (3.2%)	-	-
Pre-dorsal fin origin	71–85 (40%–41.7%)	56 (38.4%), 116 (44.6%)	-	58.1 (40.9%), 61.4 (41.2%)
Pre-adipose fin origin	141–174 (80.1%–85.3%)	118.1 (80.8%), 217 (83.5%)	-	114.6 (80.7%),122.5 (82.2%)
Preanal fin origin	139–162 (79%–79.4%)	115 (78.8%), 209.3 (80.5%)	-	112.4 (79.2%), 119.2 (80%)
Pre-pelvic fin origin	58–71 (30.9%–34.6%)	48.2 (32.8%), 85.3 (33%)	-	49.9 (35.1%), 51.5 (34.6%)
Pre-pectoral fin origin	45–52 (23.90%–25.6%)	37.5 (25.7%), 68 (26.2%)	-	37 (24.8%), 38.2 (26.9%)
Meristic characters				
Dorsal fin rays	12–13	13	13	13, 14
Anal fin rays	8–9	8	9	9
Pectoral fin rays	11–13	12	-	12
Ventral fin rays	8	8	8	8
Pored lateral-line scales	52–65	59	57	56, 57
Scales above the lateral to the dorsal fin	5–5.5	4	5	3.5
Scales below the lateral line to the anal fin	7.5–8	-	7	
Number of teeth on the free end of the tongue	48–50	25, 50	-	-
Peritoneal spots	14–15	-	-	11

SL, standard length.

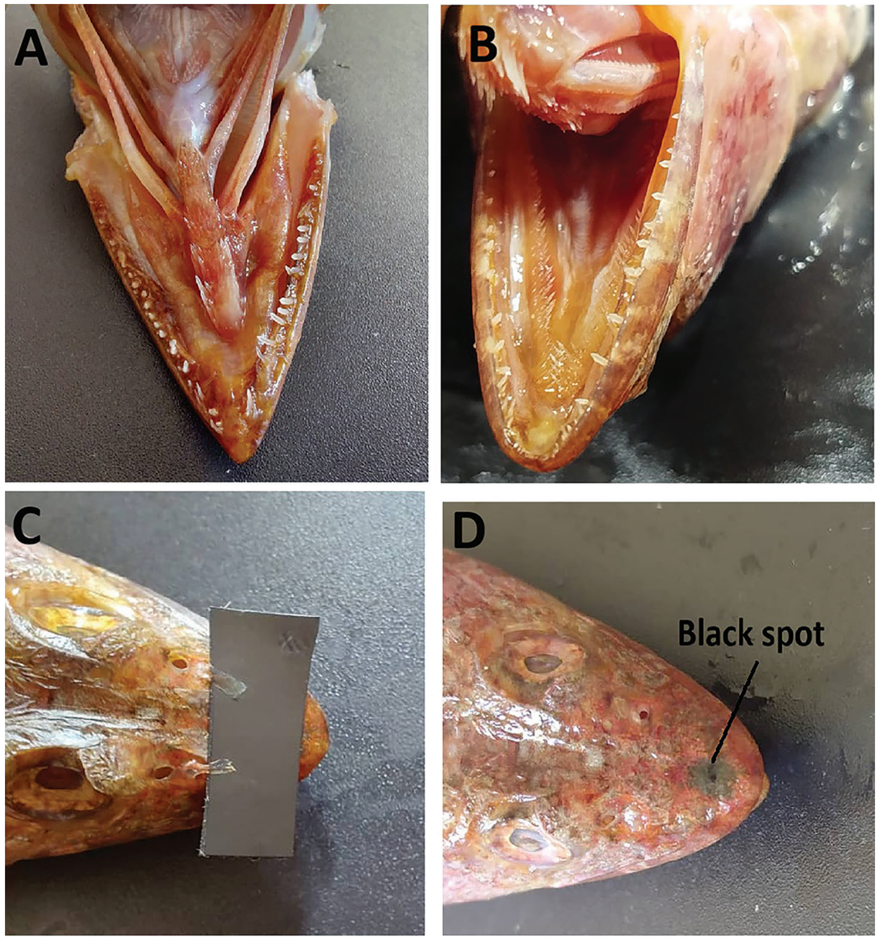

Figure 3

S. synodus specimen (194 mm TL) showing: **(A)** lingual teeth, **(B)** palatine teeth, **(C)** nostril flaps, and **(D)** black spot-on snout.

78.97%–79.41% SL, respectively. Meristic counts also showed limited variation: dorsal fin rays ranged from 12 to 13, anal fin rays from eight to nine, and pectoral fin rays from 11 to 13, while pelvic fin rays were consistently eight in all specimens. The number of pored lateral-line scales ranged from 52 to 56, and scales above the lateral line ranged from 5 to 5.5. The number of teeth on the free end of the tongue ranged from 48 to 50, and peritoneal spots varied from 14 to 15. These morphometric and meristic features are consistent with previous descriptions of *S. synodus* from other localities.

4. Discussion

The observation that the three *S. synodus* specimens examined in the study are larger than those reported from Greece, Italy (Di Franco et al., 2026), and Lebanon (Farhat et al., 2026), while aligning with the size range of specimens from Malta (Deidun et al., 2025), carries significant ecological and biogeographical meaning (Berkeley et al., 2004). To fully appreciate this result, it is essential to contextualize it within the species' known biology and its recent history in the Mediterranean Sea.

The fact that the specimens of the present study and those from Malta are larger than those from the Greek, Italian, and Lebanese studies is intriguing and could point to several underlying factors: different population demographics: larger average sizes indicating a more established or mature population. A population that has been present in an area for a longer time may contain a higher proportion of older, larger individuals. The fact that Malta now has confirmed records and a photographed individual suggests a stable presence of the species, which is consistent with the larger sizes observed there and reported in the study by Denney et al. (2002). Conversely, the smaller sizes reported in Greece, Italy, and Lebanon could represent younger populations that are still in the early stages of colonization, consisting mostly of smaller, younger individuals; regional environmental conditions: fish growth rates are strongly influenced by environmental factors such as sea temperature and prey availability. The Mediterranean Sea has significant environmental gradients, with the eastern basin being warmer and more oligotrophic (nutrient-poor) than the central and western basins. Differences in these conditions between the central Mediterranean (Malta, present study site) and the Aegean/Ionian Seas (Greece, Italy) and the Levantine Basin (Lebanon) could lead to variations in growth rates and thus the size structure of local populations (Di Franco 2026). A more favorable environment with ample food could allow fish to reach larger sizes.

Sampling artifacts: It is also important to consider the limitations of the data. The present study is based on only three specimens. Similarly, the other studies are also based on relatively small sample sizes. Deidun et al. (2025), for instance, reported on just two caught specimens. Therefore, the observed size differences, while noteworthy, could be influenced by the chance capture of a few unusually small or large individuals and may not fully represent the entire population in those regions. Moreover, this result contributes an important data point to the emerging picture of how *S. synodus* is establishing itself across the Mediterranean. By reporting specimens that are larger than those found in the eastern and parts of the central basin, the present study highlights the potential for regional variability in the colonization process (Agostinho et al., 2016). It suggests that the population dynamics of this 'neonative' species (one expanding its range naturally, not through human introduction) may not be uniform across its new habitat (Ragkousis et al., 2023). The present findings, in conjunction with those from Malta, Greece, Italy, and Lebanon, collectively underscore the importance of continued monitoring to understand how environmental gradients and population maturity influence the success and spread of range-expanding species in a rapidly changing Mediterranean Sea.

The comparative morphometric and meristic data presented in Table 1 provide valuable insights into the phenotypic variation of *S. synodus* across its expanding Mediterranean range. The total length of specimens from the Libyan coast (194–233 mm) falls within the broader range reported by Deidun et al. (2025) from Malta (166.1–300.2 mm) but exceeds those documented by Di Franco et al. (2026) from Greece and Italy (238–265 mm SL) and Farhat et al. (2026) from Lebanese waters (160–168 mm total length), suggesting potential regional disparities in population structure (Agostinho et al., 2016). Notably, the meristic characters observed in Libyan specimens—including dorsal fin rays (12–13), anal fin rays (8–9), and pored lateral-line scales (52–65)—are generally consistent with values reported across all comparative localities, indicating that these counts are stable taxonomic features (Gonzalez-Martinez et al., 2020). However, the slightly higher range of pored lateral-line scales (up to 65) and the greater number of teeth on the free end of the tongue (48–50) recorded in the present study warrant further investigation, as these may reflect either intraspecific variation or differences in counting methodologies among research groups (Winans, 1985). The proportional morphometric ratios, such as head length as a percentage of total length (24.9%–26.7%) and pre-dorsal fin origin (40.0%–41.7%), align closely with those from Malta and Lebanon, reinforcing the general morphological consistency of this species across geographically disparate populations (Deidun et al., 2025; Farhat et al., 2026). Collectively, these findings contribute to the growing body of knowledge on the biometric variability of *S. synodus* in the Mediterranean Sea, emphasizing the need for standardized sampling protocols to discern true geographic variation from methodological artifacts, particularly as this species continues to establish and expand its presence throughout the basin.

The species has been documented in the Mediterranean (Kovačić et al., 2021), yet published information regarding its distribution across the basin remains scarce, with the exception of Egyptian waters (Akel & Karachle, 2017). In Mediterranean Egyptian waters, it is occasionally captured and morphologically distinguished from other sympatric synodontids, such as *S. lessepsianus* and *S. saurus*, with recorded total length ranges for *S. synodus* of 16.7–23.6 cm (Abdallah, 2002) and 13–19 cm (Akel, 2020). Notably, in situ observations of *S. synodus* in the Mediterranean have been documented in the Global Biodiversity Information Facility: in 2002 from Akrotirion Gatas/Cape Greco, southeastern Cyprus (Staatliches Museum für Naturkunde Stuttgart 2025); in 2008 from Santa Pola (Alicante), Spain (Conselleria de Medio Ambiente, Agua, Infraestructuras y Territorio. Generalitat Valenciana 2024) and Chania Gulf, Crete, Greece (Casassovici & Brosens, 2022a); and in 2013 from Cape Palos (Cartagena), Spain (Casassovici & Brosens, 2022b).

The recent documentation of another *Synodus* species, *S. randalli*, from the eastern Mediterranean in Iskenderun and Mersin bays, Türkiye (Erguden et al., 2024; Langeneck et al., 2023), and from Crete, Greece (Christidis & Kosoglou, 2024), raises the question of whether the *Synodus* species reported from Turkish waters of the eastern Mediterranean Sea is indeed *S. randalli* rather than *S. synodus*, as these two species are morphologically very similar. For instance, the external morphology, coloration, and meristic features of the *S. synodus* specimens collected by Deidun et al. (2025) from Malta and those examined in the present study closely resemble the specimens reported as *S. randalli* from Turkish and Greek waters. Furthermore, a dark blotch at the tip of the snout—a well-documented diagnostic trait of *S. synodus* (see Anderson et al., 1966a, 1966b; Fischer et al., 1981; Fowler, 1936; Lavett Smith, 1997; Sulak, 1984)—can be observed in the image of the specimen identified as *S. randalli* from Iskenderun (Langeneck et al., 2023). Although two or four dark markings on the snout are present in some *Synodus* species from the western Indian Ocean and Hawaii (Randall, 2009; Russell, 2022; Waples & Randall, 1988), such similarities underscore the urgent need to verify the identity of the specimens reported as *S. randalli* from Iskenderun.

Knowledge of the ecology of small cryptobenthic fish species in general and triplefins, in particular, is lacking in Libyan waters. The reason *S. synodus* was not recorded before in the Mediterranean Sea coasts of Libya might be that adequate sampling is not available. The use of diverse fish sampling techniques in the area, including scuba diving and underwater photography, has already ended the alleged rarity of several species (Jawad & Al-Mamry, 2009; Jawad et al., 2010). The present record of *S. synodus* confirms that trend. *S. synodus* was previously recorded in the Mediterranean Sea coasts of Egypt (Abdallah, 2002; Akel, 2020). Thus, from a mere geographical point of view, its presence was to be expected in the Libyan coasts of the Mediterranean Sea, located further west. However, climatic, hydrological, and ecological differences between these three areas, including contrasting seasonal changes, result in some discrepancies in the local ichthyofauna (Randall, 1995).

S. synodus may have established previously undetected populations across a wide expanse of Libyan Mediterranean waters, with individuals reaching considerable sizes, a pattern that points to not only successful colonization but also a level of ecological persistence that has gone unnoticed until now. Although molecular analyses were not conducted in this study, the consistent and diagnostic morphological features of *S. synodus* enabled reliable identification, an accuracy further supported by DNA-confirmed records from the region (e.g., Deidun et al., 2025), which lend independent weight to our taxonomic conclusions. Together, these lines of evidence reveal a striking case of cryptic establishment by a species that is far from inconspicuous, underscoring how even visually recognizable marine organisms can evade detection for years. This phenomenon highlights the profound challenges facing researchers and resource managers in tracking rapid shifts in marine biota, particularly as warming seas accelerate range expansions and alter community compositions faster than conventional monitoring efforts can capture.

The occurrence of *S. synodus* along the Libyan coast carries substantial ecological and zoogeographical significance, particularly when considered within the broader context of the species' ongoing range expansion across the Mediterranean Basin. Ecologically, the larger body sizes recorded in Libyan specimens suggest the presence of more established or mature populations in the central Mediterranean, where longer colonization periods or favorable environmental conditions, such as enhanced prey availability, may facilitate greater individual growth (Berkeley et al., 2004; Denney et al., 2002). This size disparity hints at regional variability in population demographics, potentially reflecting differences in the timing of establishment or local habitat suitability (Agostinho et al., 2016). Zoogeographically, the Libyan record fills a critical distributional gap between previously documented populations in Egyptian waters (Abdallah, 2002; Akel, 2020) and those further west in Malta and the central Mediterranean, reinforcing the view that *S. synodus* is progressively consolidating its presence along the North African shelf. The species' apparent absence from Libyan waters until now, despite its known occurrence in neighboring Egypt, underscores how even conspicuous species can evade detection due to historical under-sampling, a trend increasingly rectified by the deployment of diverse survey techniques such as underwater photography and SCUBA diving (Jawad & Al-Mamry, 2009; Jawad et al., 2010). Moreover, the morphological similarity between Libyan *S. synodus* and specimens reported as *S. randalli* from the eastern Mediterranean (Erguden et al., 2024; Langeneck et al., 2023) raises important taxonomic questions, emphasizing the need for molecular validation to clarify species identities and accurately map the distribution of synodontids in the region (Ragkousis et al., 2023). Collectively, these findings illustrate how range-expanding species can exhibit heterogeneous colonization dynamics across environmental gradients and they highlight the necessity of sustained, standardized monitoring to discern true biogeographic patterns from sampling artifacts in a rapidly warming Mediterranean Sea.

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Conflict of interest statement

There are no conflicts of interest, financial or otherwise, that could influence the contents of this paper.

Data availability statement

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Ethics statement

This work is based on widespread non-threatened fish species. Therefore, ethical aspects are not applicable.

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