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Nefeli Tsaousi and Stefanos Kalogirou *

Posted Date: 29 April 2024

doi: 10.20944/preprints202404.1928.v1

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Article

First Record of the Red Cornetfish *Fistularia petimba* Lacepède, 1803 from Amorgos Island (Central Aegean Sea; Greece) and a Review of Its Current Distribution in the Mediterranean Sea

Nefeli Tsaousi and Stefanos Kalogirou *

Agricultural University of Athens; tsaousinefeli@gmail.com
* Correspondence: stefanos.kalogirou@aua.gr; Tel.: +302105294459

Abstract: The rapid spread of non-indigenous species (NIS) poses a significant threat to biodiversity globally, with the Mediterranean region being particularly susceptible due to increased human activities and its status as a marine biodiversity hotspot. In this study, we focus on the introduction and distribution of *Fistularia petimba*, a member of the Fistulariidae family, in the eastern Mediterranean Sea, specifically on the coasts of Amorgos Island, Greece. Through a baseline fisheries study conducted over 12 months, utilizing experimental sampling with gillnets, trammel nets, and longlines, one individual of *F.petimba* was captured off the coast of Katapola Bay. Morphological examination confirmed its identity, with measurements on meristic characteristics obtained and stomach content analyzed. This finding represents a significant addition to the documented distribution of *F. petimba* in the Mediterranean Sea, particularly in the Aegean Sea, underscoring the importance of ongoing research in uncovering new occurrences and expanding our understanding of marine biodiversity and ecosystem changes. Further investigation into the ecological preferences and population dynamics of *F.petimba* in the Aegean Sea is crucial for informed conservation and management efforts.

Keywords: *Fistularia petimba*; red cornetfish; Mediterranean Sea; invasive species; NIS; Lessepsian species

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1. Introduction

One of the main threats that biodiversity is currently facing is the rapid spread of non-indigenous species (NIS). NIS are defined as the array of species spreading outside their natural or native distribution range [1]. Different areas worldwide have been experiencing vast impacts from the introduction of non-indigenous species, oftenly related to increased human activities such as, opening of canals, the continuous growth of the shipping industry across biogeographic barriers [2,3], a wide range of changes in water temperature due to climate change [4–6], fishing pressure [7–9] and habitat degradation or loss of species [10–12]. In the studied area of the Mediterranean Sea, recognized as one of the main hotspots of marine biodiversity [13,14], the effects of NIS are apparent both in terms of introduction rate [15] and number of introduced species [16], leading to the global acknowledgment of the Mediterranean region as hotspot area for NIS [17]. Additionally, recent findings during the past decades, points Mediterranean ports as a major hotspot for the introduction of NIS in this basin [18,19].

A region where visible changes in aquatic biodiversity have occurred is the eastern Mediterranean Sea where a rapid introduction of fish species with Indo-pacific origin are observed, i.e. the Levantine Sea [20–23], raising significantly the overall amount of fish biomass up to 90% in specific habitats [24,25]. Though, Indo-Pacific fish species could potentially arrive through various ways in the Levantine basin, most likely by immigration path through the Suez Canal which opened to shorten the commercial shipping ways between the Indian Ocean and the Mediterranean Sea in

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1869 [26]. It is assumed that species that normally resided in the Red Sea and the Indian Ocean traversed through the Suez Canal, and proceeded northwards along the Levant coast actively or passively aided by human activity [27]. These species were named Lessepsian after the name of the constructor of the canal Engineer and Diplomat Ferdinand de Lesseps [28].

The aforementioned group of Lessepsian species established in the Mediterranean Sea, currently includes *Fistularia commersonii* [29] and *Fistularia petimba*, which belong to the Fistulariidae (order of Syngnathiformes), also called cornetfishes or flutemouths. There is only one genus in this family, Fistularia, with four different species: *Fistularia commersonii* Rüppell, 1838, *Fistularia corneta* Gilbert & Starks, 1904, *Fistularia petimba* Lacepède, 1803 and *Fistularia tabacaria* Linnaeus, 1758 [30]. The species *F.tabacaria* inhabits the tropical Atlantic, while its closest relative, *F. commersonii*, inhabits the Pacific and Indian Oceans. *F. petimba* spans the tropical Atlantic and Indo-West Pacific Oceans, whereas *F. corneta* is confined to the tropical eastern Pacific [31]. Fistularidae species are predators, inhabiting shallow waters of tropical and subtropical areas [31]. Although *F. commersonii* originated from the Indo-Pacific region [32] a widespread geographical distribution pattern has been observed in the eastern part of the Mediterranean Sea [33] with multiple sightings of this Lessepsian immigrant as a result of the opening of the Suez Canal in 1869. Due to its rapid growth and reproduction cycle, it has successfully formed large populations in the areas where it has been observed, with notable ecological impacts on the native species [34]. *Fistularia commersonii* is a piscivorous species mainly feeding on smaller fish and complements its diet with some Crustacea species. As the size of the species increases, there is a corresponding increase in the size of the prey consumed [34].

Another member of the Fistulariidae family is the red cornetfish, *F. petimba* which is naturally distributed in the Indo-West Pacific, the tropical Atlantic [32], the East Atlantic Ocean [35] and with a time lag of 20 years of its first citing in the western Mediterranean Sea (1996) it has the last ten years reported from several locations in the eastern Mediterranean Sea [36,37]. In this study, we show the immigration path of *F.petimba* in the eastern Mediterranean Sea through a stepping stone process of establishment through the Suez Canal [38,39].

2. Materials and Methods

Sampling Methodology

A monthly experimental fishery sampling was performed in Amorgos Island, Central Aegean Sea, between September 2022 and August 2023 (Figure 1).

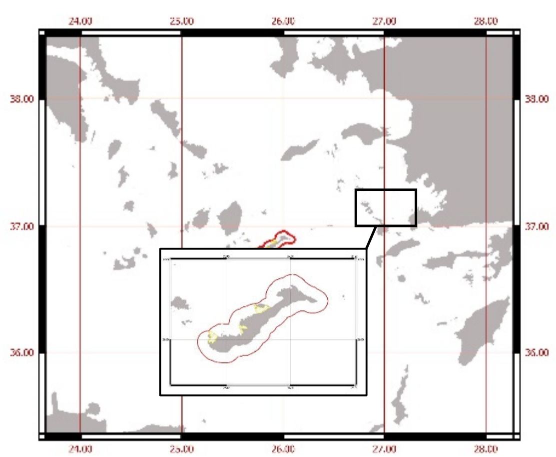

Figure 1. Map of the study area in Amorgos Island, Greece. The red line marks the proposed seasonal Fisheries Restricted Areas (FRAs), while the yellow areas indicate the proposed permanent FRAs.

The sampling method used was three types of gears: Gillnets (GNS), Trammel nets (GTR), and Long Lines (LLS). The gears used were designed to study the population dynamics of targeted fisheries species.

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For GNS and GTR, nine different mesh sizes (20, 22, 24, 26, 28, 30, 32, 36, 45) and for LLS six different hook sizes (9, 10, 11, 12, 13, 14) were used to reflect the most commonly used mesh and hook sizes in small-scale fisheries of the Aegean Sea.

The nets used in this study had a total length of 900 meters, consisting of 100-meter panels for each of the nine mesh sizes. The height of each compartment was 100 meshes. The arrangement of mesh sizes for both GNS and GTR were randomly selected and illustrated in Figures 2 and 3. For longlines, each compartment had a length of 200 meters and equipped with 200 hooks (100 hooks per hook size). One compartment comprised of the hook sizes 9 and 10, and two more compartments comprised of the combinations of hook sizes 11 – 12, and 13 – 14, respectively.

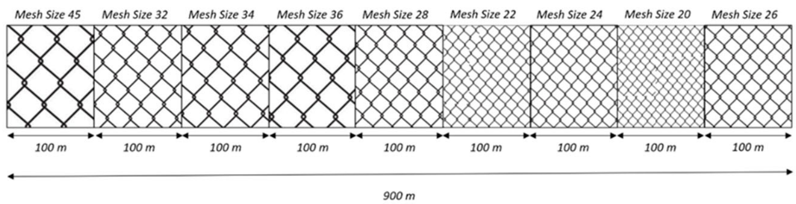

Figure 2. GNS mesh size arrangement on this study.

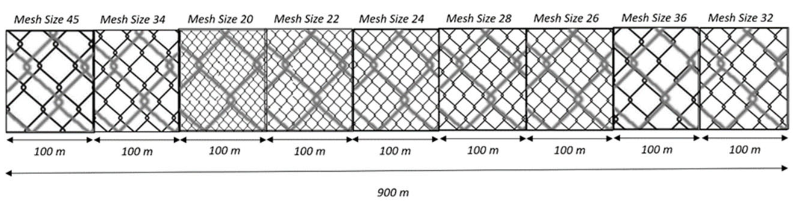

Figure 3. GTR mesh size arrangement on this study.

All samples were stored in a freezer (-20^{o}C) until transported to the Laboratory of Applied Hydrobiology of the Agricultural University of Athens, Greece, for further examination.

Identification of the Species

Fistularia petimba was identified based on its morphological characteristics [31] following the genus description given by *Fritzsche (1976)*: Fistularia species can be identified by their elongated body. Juveniles of this genus display a specific form, known as the "villosa Form" described by Liitken in 1880, characterized by rows of small hooked spinules on their bodies, which may or may not persist into adulthood. Notably, these fish may have elongated bony plates along the midline of their body anterior to the dorsal or anal fins. Their lateral line curves anteriorly, almost reaching the middle of their back, and extends posteriorly into a filament produced by the middle two caudal rays. Occasionally, the posterior lateral line ossifications bear sharp retrorse spines. They possess a small terminal mouth at the end of their elongated snout, and the first four vertebrae are fused, with a total vertebra count ranging from 76 to 87. Their teeth, found on the premaxillae, dentaries, and pharyngobranchials, are small. Notably, they lack a spinous dorsal fin, and both their dorsal and anal fins are short-based and opposed, each typically having 13-20 rays. Their caudal fin features 14 rays (7+7), and their branchiostegals are usually arranged in a pattern of 3 + 2 or 2 + 3.

Fistularia petimba is distinguished from its confamilial species by its specific morphological features [31]: number of rays on the dorsal fin (13-17), the anal fin (13-16) elongated bony plates embedded in the skin along the midline of the back, with posterior lateral line ossifications terminating in a retrorse spine. These distinctive traits served to distinguish *F. petimba* from other species of the same genus (Figure 4).

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(**a**) (**b**)

Figure 4. *Fistularia petimba* individual from Amorgos Island and its identification characteristics: (a) reddish colour and (b) elongate bony plates embedded in skin.

The following morphometric characteristics were measured to the nearest second decimal in mm or g: Total Length without filament (TL), Total Length with filament (TLf), Filament Length (fL), Standard Length (SL), Fork Length (FL), Body Deth (BD), Head Length (HL), Eye Diameter (ED), Snout Length (SN), Dorsal Fin Length (DFL), Dorsal Fin Height (DFH), Pectoral Fin Length (PFL), Pelvic Fin Height (PFH), Dorsal Fin Length (PvFL), Pelvic Fin Height (PvFH), Caudal Fin Length (CFL), Caudal Fin Height (CFH), Anal Fin Length (AFL), Anal Fin Height (AFH), Pre-dorsal Fin Length (pDFL), Pre-dorsal Fin Height (pDFH), Pre-pectoral Fin Length (pPFL), Pre-pectoral Fin Height (pPFH), Pre-pelvic Fin Length (pPvFL), Pre-pelvic Fin Height (pPvFH), Pre-anal Fin Length (pAFL), Pre-anal Fin Height (pAFH) and Total Wet Weight (TWW).

Stomach Content and Sex Maturity

The stomach contents were analyzed using the frequency of occurrence method, supplemented by the identification of the number of individuals and taxonomic classification to the lowest possible level [40–42].

Sex and maturity stages were assessed by macroscopic examination using a 5-stage scale: (a) immature, (b) maturing, (c) mature – spawning, (d) spent and (e) resting [43–45].

Distibution of F.petimba in the Mediterranean Sea

In order to, compile a map with records of *F.petimba* in the Mediterranean Sea, a literature review (until February 2024) was performed using Google Scholar. This review used two main keywords, namely "*Fistularia petimba*" and "Red cornetfish" together with additional keywords to extend and maximize the capture probability of *F.petimba* records: "Mediterranean Sea", "Invasive species", "NIS", "ecology", "habitat" and "lessepsian".

To visualize the species' geographical distribution in the Mediterranean Sea, a map illustrating the occurrences of *F.petimba* was generated using ArcGIS [46] and by integrating data from this study and published records from scientific journals.

3. Results

An individual of *F.petimba* (Figure 4) was captured with GTR with a mesh size of 26 mm, deployed between 24.5 m and 30.6 m depth on the 27th of May 2023 at 7:50 PM and hauled on the 28th of May 2023 at 6:40 AM (soak time 11 hours and 50 minutes), off the coast of Katapola Bay, Amorgos Island, Greece (lon="25.85879922" lat="36.82760281"). The measurements for each of the morphometric characteristics of the species are presented in Table 1.

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Table 1. Morphometric characheristics and measurements of *Fistularia petimba* from Amorgos Island, Greece.

Morphometrics	Measurement (mm or g)
Total Length without filament (TL)	395.00
Total Length with filament (TLf)	530.00
Filament Length (fL)	124.23
Standard Length (SL)	378.00
Fork Length (FL)	383.00
Body Deth (BD)	7.98
Head Length (HL)	142.00
Eye Diameter (ED)	10.97
Snout Length (SN)	114.00
Dorsal Fin Length (DFL)	15.41
Dorsal Fin Height (DFH)	28.89
Pectoral Fin Length (PFL)	6.66
Pelvic Fin Height (PFH)	16.81
Dorsal Fin Length (PvFL)	2.54
Pelvic Fin Height (PvFH)	6.83
Caudal Fin Length (CFL)	19.01
Caudal Fin Height (CFH)	5.10
Anal Fin Length (AFL)	15.16
Anal Fin Height (AFH)	27.37
Pre-dorsal Fin Length (pDFL)	67.00
Pre-pectoral Fin Length (pPFL)	319.00
Pre-pelvic Fin Length (pPvFL)	190.00
Pre-anal Fin Length (pAFL)	310.00
Total Wet Weight (TWW)	34.00

The stomach of the individual was empty. Following macroscopic examination no gonads were identified and thus sex or maturity stage could not be determined.

4. Discussion

The expansion of global trade and travel has increased the chances for species to migrate beyond their native ranges [47,48]. This immigration often reflects the traffic patterns within regional or worldwide transportation systems. When an area is invaded, it becomes a source for the subsequent spread of the organism to other locations in the basin [49].

The Suez Canal, since its completion in the late 19th century, has served as a major conduit for the immigration of marine organisms between the Red Sea and the Mediterranean Sea. This artificial connection has facilitated the establishment of numerous NIS in the Mediterranean basin, reshaping the region's biodiversity and ecological dynamics [50].

Marinas in the Mediterranean Sea are significant areas, not only for the initial introductions of NIS, but also for subsequent secondary invasions, acting as stepping stones in the spread of NIS [48,51].

In the marine environment, NIS can become invasive, resulting in the displacement of indigenous species and thus leading to a range of negative consequences. These effects encompass the loss of native genetic diversity, alterations to habitats, shifts in community composition, changes to food web dynamics and ecosystem functions, disruptions to the provision of ecosystem services, threats to human health, and significant economic damages [52].

The capture of *Fistularia petimba* specimen in Amorgos Island, Central Aegean Sea represents a significant addition to the existing knowledge of the species' distribution in the Mediterranean region. Prior to this finding, there were 31 citings in the Mediterranean Sea, out of them only one was documented in the Aegean Sea, specifically in Samos (Figure 5, Table 2).

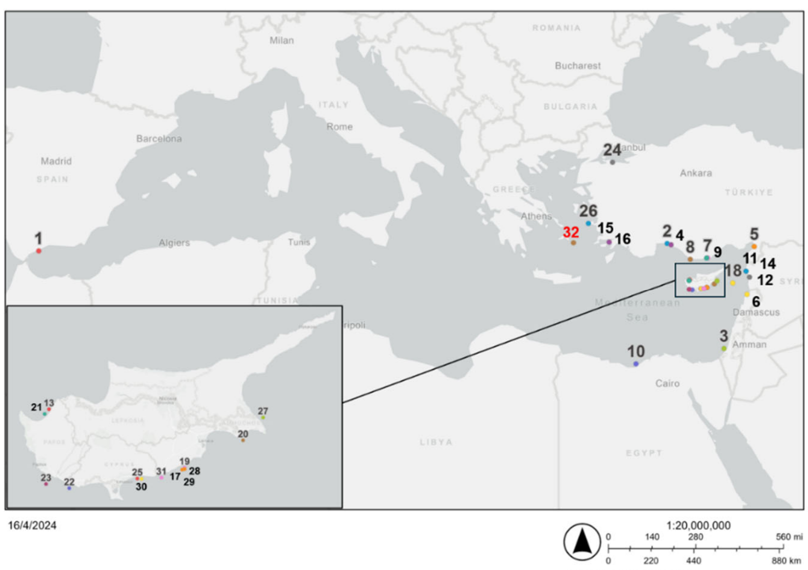

Figure 5. Citings of *Fistularia petimba* in the Mediterranean Sea [46].

Table 2. Data of the 32 citings of *Fistularia petimba* in the Mediterranean Sea.

No	Location	Latitude	Longitude	Date (capture)	Depth (m)	Gear Type	Sample size
1	Cadiz, Spain [36]	36.455097	-4.703372	23/06/1996	50	Gillnet	1
2	Antalya Bay, Turkey [37]	36.793556	31.209167	28/10/2016	35 – 43	Bottom trawl	1

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3	Ashdod, Israel [29]	31.813950	34.459717	12/11/2016	80	Bottom trawl	1
4	Antalya Bay, Turkey [37]	36.737417	31.434361	26/11/2016	30	Bottom trawl	1
5	Iskenderun, Turkey [37]	36.654400	36.186183	21/05/2017	35 – 38	Bottom trawl	2
6	Tripoli, Lebanon [53]	34.410000	35.770000	15/11/2017	N/A	Gillnet	1
7	Mersin Bay, Turkey [39]	36.128833	33.520667	22/11/2017	95	Bottom trawl	1
8	Antalya Bay, Turkey [39]	36.061867	32.534233	09/01/2018	70	Bottom trawl	2
9	Büyükeceli Coast (Mersin Bay)Turkey [38]	36.123139	33.467944	05/10/2018	150	Bottom trawl	2
10	Egypt [30]	El-Hamam - Sidi Kirayr.		09/03/2019	40 – 60	Bottom trawl	1
11	Lattakia, Syria [54]	35.518325	35.713492	29/07/2019	45	Gillnet	1
12	Lattakia, Syria [55]	35.243086	35.920000	24/09/2019	30	Gillnet	1
13	Gialia, Cyprus [56]	35.110000	32.490000	26/09/2019	55	Gillnet	1
14	Banyas, Syria [55]	35.518325	35.713492	29/09/2019	45	Gillnet	2
15	Gökova Bay, Turkey [57]	36.857889	27.896556	19/10/2019	15 – 20	Longline	1
16	Güllük Bay, Turkey [57]	36.857883	27.896561	17/11/2019	65	Bottom trawl	4
17	Cyprus [58]	34.747367	33.463400	14/07/2020	55	Bottom trawl	3
18	Cyprus [58]	34.964500	34.964500	15/07/2020	48	Bottom trawl	1
19	Cyprus [58]	34.759617	33.480650	16/07/2020	33	Bottom trawl	1
20	Cyprus [58]	34.924100	33.908050	24/07/2020	79	Bottom trawl	11
21	Cyprus [58]	35.081733	32.458700	24/07/2020	43	Bottom trawl	29
22	Cyprus [58]	34.635717	32.638517	27/03/2021	46	Bottom trawl	10
23	Cyprus [58]	34.661300	32.468650	27/03/2021	93	Bottom trawl	4

24	Bandirma Bay, Turkey [53]	40.416950	28.084000	11/06/2021	32	Trammel net	1
25	Cyprus [58]	34.693983	33.135567	04/08/2021	44	Bottom trawl	26
26	Samos, Greece [53]	37.706583	26.708783	07/11/2021	20	Trammel net	1
27	Cyprus [58]	35.060833	34.054383	08/08/2021	86	Bottom trawl	4
28	Cyprus [58]	34.750917	33.480933	08/08/2021	55	Bottom trawl	7
29	Cyprus [58]	34.750917	33.480933	08/08/2021	33	Bottom trawl	2
30	Cyprus [58]	34.692267	33.166750	08/08/2021	56	Bottom trawl	1
31	Cyprus [58]	34.699333	33.311817	13/09/2021	13	Trammel net	1
32	Amorgos, Greece (current study)	36.82760281	25.85879922	28/05/2023	24.5 - 30.6	Trammel net	1

The first record in Cadiz, Spain appears to be an incidental catch from the endemic habitat in the Atlantic Ocean. The following documented occurrences of the Lessepsian immigrant, *F. petimba*, within the Mediterranean basin reveal a pattern of its progressive invasion into novel habitats. Having originated in the Red Sea, this species initiated a significant dispersal path along the coastlines of Syria, Egypt and Turkey. The species' course is validated with documented sightings in the area of Cyprus, concluding its eventual establishment within the Aegean Sea. Each documented occurrence represents a critical point in the species' biogeographic spread throughout the Mediterranean Sea.

This interpretation of chronological milestones offers valuable insights into the stepping-stone spreading pattern characterizing *F. petimba*'s invasion in the Mediterranean Sea. Tracing its cross-border path from Red Sea to the Aegean Sea, provides researchers with a deeper understanding of the mechanisms of invasive populations' establishment within marine ecosystems.

According to *Papageorgiou et al., 2023* the mean total length for gonad maturity is 440 mm for females and 410 mm. The specimen of this study (390 mm) also agrees with those results as no gonads were visible macroscopically. There was no histological examination performed.

The occurrence of this species in Amorgos Island suggests a wider presence within the Aegean Sea than previously recognized. This finding underscores the importance of ongoing fisheries research in uncovering new occurrences and expanding our understanding of marine biodiversity in the region. Further investigations into the ecological preferences, population dynamics, and potential impact of *Fistularia petimba* in the Aegean Sea and the Mediterranean basin are important to understand succession rates and ecological impacts to enhance conservation efforts and inform sustainable management practices.

Acknowledgments: The authors thank the Blue Marine Foundation (BMF) and Cyclades Preservation Fund (CPF) for their support, as well as, the Professional Fishing Association of Amorgos and Ioannis Vekris for their expertise and assistance throughout all aspects of our study.

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Funding: This research was co-funded by Blue Marine Foundation (BMF) and Cyclades Preservation Fund (CPF) – Conservation Collective (CC) under the project entitled "Base line study for fisheries management on coastal areas based on local ecological knowledge in Amorgos Island".

Conflicts of Interest: The authors declare no conflict of interest.

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