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RESEARCH ARTICLE

Alien species in southern Laconia, Kythira Island and southern Messenia (Greece): new and additional records and updated record maps

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Abstract

Six non-indigenous species are recorded from southern Laconia, Elafonisos Island, Kythira Island and Messenia (Greece, Mediterranean Sea) along regularly observed transects, including updates to their distribution maps (status year-end 2019). The sightings of *Pterois miles* (Scorpaeniformes, Scorpaenidae), *Diadema setosum* (Diadematoida, Diadematidae), *Torquigener flavimaculosus* (Tetradontiformes, Tetradontidae), *Abudefduf vaigiensis* (Perciformes, Pomacentridae), *Stephanolepis diaspros* (Tetradontiformes, Monacanthidae) and *Enchelycore anatina* (Anguiliformes, Muraenidae) represent either first regional records or confirm the presence of the respective taxon. Observable morphological characteristics of the individuals are presented and discussed in the context of general morphological information. Distribution of the taxa is discussed in the context of the general current regime of the eastern Mediterranean Sea. Additionally, a simple method for counting large numbers of fish individuals based on point counts using underwater images is presented.

Keywords: Non-indigenous species, Mediterranean Sea, *Pterois miles*, *Torquigener flavimaculosus*, *Abudefduf vaigiensis*, *Diadema setosum*

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Introduction

The impact of alien species on regional environments in areas with established non-indigenous populations in the Levantine Sea has been investigated for some time (e.g. Golani 1998). Impacts of non-indigenous taxa on native biota in Turkey, Greece and areas further to the west are slowly emerging (e.g. EastMed 2010), including indications of algal denudation by now being dominant species

like *Siganus* spp. (Sala *et al.* 2011). Climate change causing an increase in sea water temperature also seems to have an influence on the faunal composition of the Mediterranean Sea (e.g. Ben Rais Lasram and Mouillot 2009), resulting in natural range expansions of subtropical to tropical Atlantic taxa and facilitating the survival of tropical Lessepsian species. Potential future range expansions of Lessepsian species and their impact on indigenous environments due to climate change have recently been modelled (D'Amen and Azzurro 2020). Especially the eastern Mediterranean Sea is predicted to continue to represent the area most susceptible to increased impact by non-indigenous taxa due to providing the most fitting climate. Other potential factors aiding a rapid spread includes the investigation of potential niche expansions, where tropical species thought to be conservative in their climatic requirements may however colonize areas of seemingly unfavourable conditions due to e.g. the presence of underutilized food sources (Parravicini *et al.* 2015). Suitable habitat analysis and the modelling of unfilled niches and their role in the propagation of non-indigenous taxa have recently been carried out. This indicates a strong niche unfilling and a higher than currently predicted spread, e.g. *Pterois miles* (Poursanidis *et al.* 2020).

Since summer 2008 field observations in the southern Peloponnese (Figure 1) have seen a rapid increase of fish species like *Siganus luridus* and *Siganus rivulatus* with breeding populations as well as the establishment of stable populations of the crab *Percnon gibbesi* (e.g. Thessalou-Legaki *et al.* 2006, Pirkenseer 2012). Besides these now-ubiquitous taxa surveys during the last few years yielded first regional observations of less common non-indigenous taxa or confirmed the presence in the respective observation areas. This includes - amongst others - the sea hare *Aplysia dactylomela* on Elafonisos Island in summer 2012 and the blue-spotted cornetfish *Fistularia commersonii* (2010) as well as the moray eel *Enchelycore anatina* (2013) in south-eastern Messenia (Pirkenseer 2012, 2013a, b).

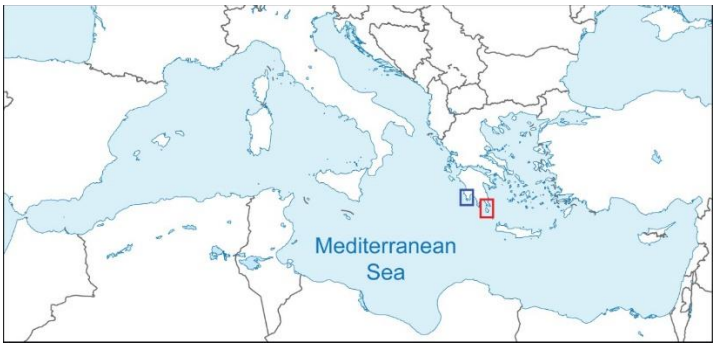


Figure 1. Research areas in the Mediterranean Sea: (blue rectangle = Messenia south of Koroni, red rectangle = Archangelos, Elafonisos Island, Kythira Island).

The observation of repeated transects in the southern Peloponnese aims at the confirmation of less common non-indigenous taxa in the investigated areas, as well as the detection of hitherto unreported alien taxa in this crucial transitional area between the eastern and central Mediterranean Sea. So far only *E. anatina* was encountered in the years following its initial observation. The summers of 2018 and 2019 – after a five year gap – however yielded regional records of four new non-indigenous taxa presented in this paper.

Methods

Between July and August from 2012 to 2019 records of taxa in the southern Peloponnese and on Kythira Island were obtained by *in situ* observation and subsequent photographic documentation of underwater biota during repeated free-diving surveys (Figure 2), with focus on rare and new taxa. Analysis of high-resolution underwater images complemented the final determination of species. Each locality was surveyed by two to seven repeated runs along predefined, between ca. 300 to 1000 m long transects with a duration of about 1½ to 3 hours and a depth up to 6 m (Table 1). The course and length of transects are shown in Figure 2. Hiding places of crepuscular and nocturnal taxa like crevices, overhangs and cave entrances were checked regularly. Transects generally followed steep rocky shores with regular observations on the adjacent flattened out rocky bottom sections or muddy/sandy bottoms to a width of about 10 to 30 m. Observation periods of individuals species ranged from a few minutes (mobile and cautious taxa) to half an hour (reclusive taxa like *E. anatina*, *P. miles*). Still images of biota were taken with Olympus TG-5, XZ-2 and Panasonic LX100/LX100II digital cameras. Shots were either illuminated by natural light, flash or underwater video light.

Individuals counts for schools of fish

Judging individual numbers underwater from schools of fish or aggregations of other taxa remains challenging. For sessile organisms, a count within a frame of about one square meter is one alternative among several (see, e.g. Eleftheriou 2013). For mobile species, including fish, estimates of large numbers of individuals without visual aids are unreliable, as has been confirmed by repeated evaluations of estimations using underwater images.

A simple way to gain accurate results is via point counts on high-resolution digital images. In a graphics editor, visible individuals can be marked with a simple design element (e.g. dot; Figure 3). Then initiate a count of these design elements. This works best with good quality images of monospecific schools. For example, adult *Siganus* spp. often school with *Sarpa salpa* (Sparidae), which was not the case here, facilitating the counts in our study.

Table 1. Surveyed coastal areas (transects indicated in Figure 2), their general environments and survey periods.

Survey area	Environment	Period
Archangelos	Exposed steep rocky shore with some crevices, overhangs and few underwater caves, sparse growth of coralline algae and sponges (e.g. *Aplysina cavernicola*).	Summers 2014-2019
Elafonisos: Village beach	Sandy to muddy bottom with two large isolated *Posidonia* patches and sparse growth of *Zostera*. Sand contains a high ratio of abraded bioclasts.	Summers 2012-2018
Elafonisos: Panagia beach	Sandy bottom without macroalgae to rocky bottom with sparse growth of algae, *Zostera*, sponges and isolated small *Posidonia* patches.	Summers 2012-2019
Elafonisos: Lefki Beach	Sandy bottom to steep rocky shore with generally sparse to locally abundant growth of algae and sponges, *Posidonia* patches close to the shore. Very clear waters, large grained sand consists mainly of abraded bioclasts and *Amphistegina* (benthic foraminifer) tests.	Summers 2012-2018
Elafonisos: South coast	Muddy rock bottom with moderate growth of filamentous macroalgae. Abundant occurrences of large adult *Muraena helena* (Muraenidae) individuals. Sand consists mainly of abraded bioclasts and *Amphistegina* tests.	Summers 2019
Avlemonas harbour	Vertical rock shore with scarce to abundant growth of macroalgae and few sponges. At around 5 m depth or deeper large *Posidonia* patches on harbour floor.	Summers 2016-2019
Avlemonas: Coast east of Palaeopoli beach	Steep rocky shore with many crevices, overhangs and small underwater caves, abundant growth of macroalgae and sponges in sheltered parts. Shore exposed to increased wave action with reduced growth or near barren rock. Close to Palaeopoli beach sandy bottoms from about 4 m depth, west facing parts of the shore partly flatten out in about 3-6 m depth with *Posidonia* patches of varying sizes.	Summers 2017-2019
South of Amoudi Beach (Messenia)	Steep rocky shore with many crevices, submerged gullies, overhangs and up to house-sized boulders. Generally abundant and diverse growth of macroalgae and sponges, seawards quick increase in water depth, scattered small *Posidonia* patches fringing boulders / outcrops.	Summers 2008-2016
North of Kalamaki Beach (Messenia)	Isolated rock outcrop with crevices surrounded by extensive sandy sea floor. Crevices colonized by abundant sponges, ophiurids and *Apogon imberbis* (Apogonidae).	Summers 2008-2016

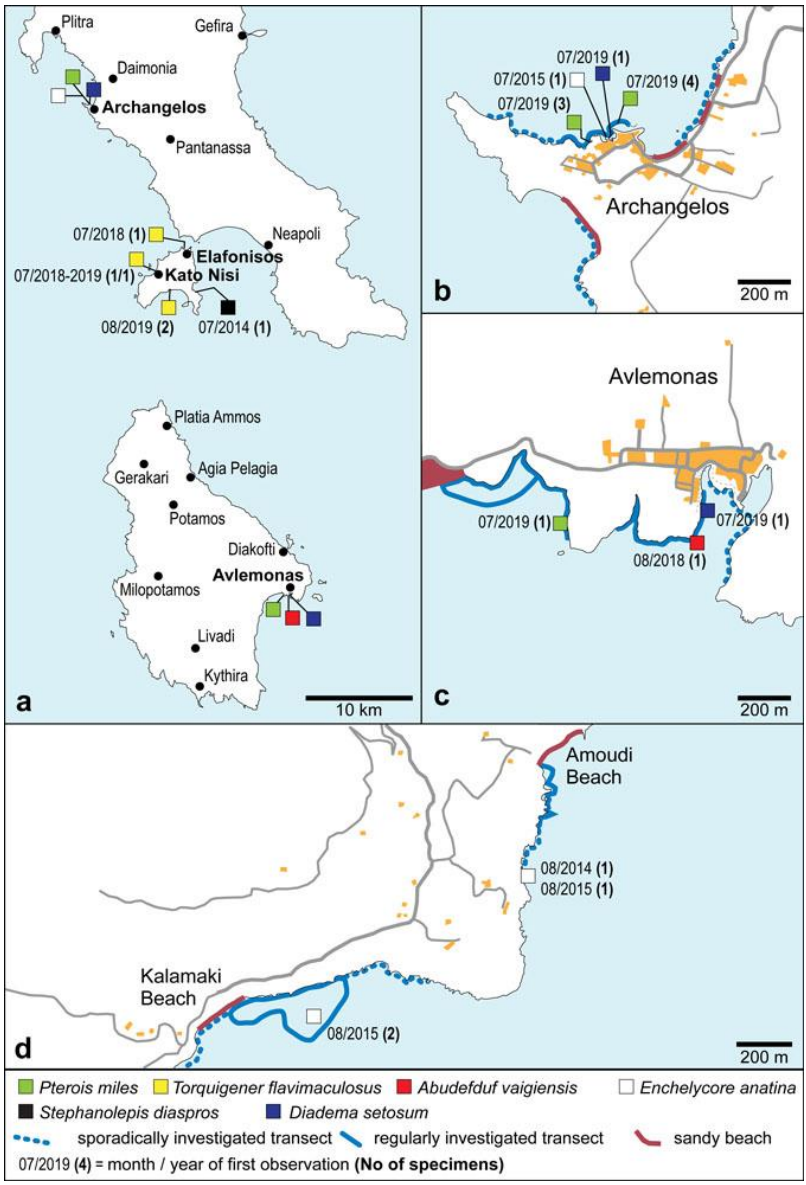


Figure 2. Maps of the surveyed localities. Individually coloured squares denote individual species (colours repeated in Figures 10 to 14), regularly investigated transects were observed for each year mentioned in Table 1, shore outside sandy beaches is rocky. **a:** Observation area in southern Laconia and Kythira Island, **b:** Archangelos area in southern Laconia, **c:** Avlemonas area in eastern Kythira Island, **d:** observation area in south-eastern Messinia, south of the town of Koroni.

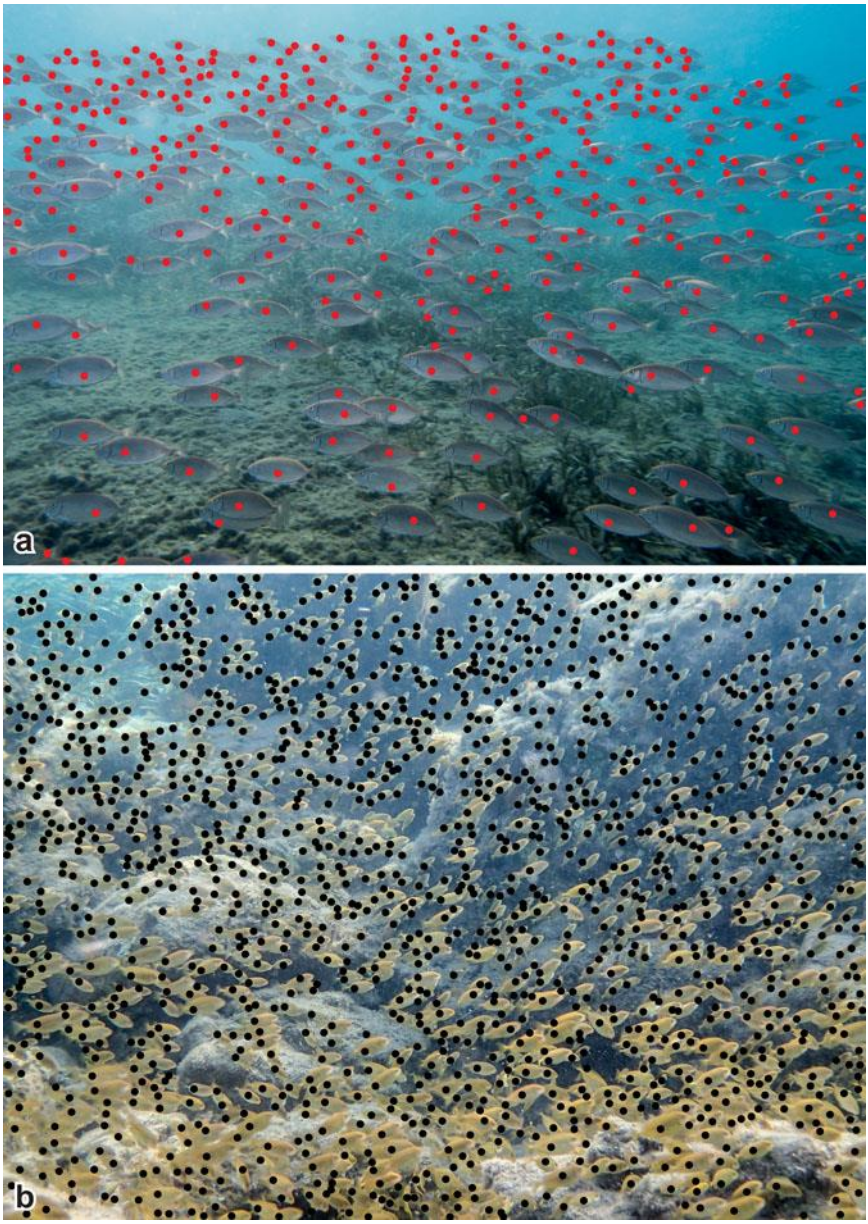


Figure 3. Point counts of schools of rabbitfish, individuals are marked by dots applied in a graphics programm. **a:** Adult individuals of *Siganus rivulatus* near Archangelos village beach (Laconia) in August 2015, **b:** juveniles of *Siganus* cf. *luridus* north of Kalamaki beach (Koroni, Messenia) in August 2013.

Results

Six non-indigenous species are recorded from southern Laconia, Elafonisos Island, Kythira Island and Messenia (Greece, Mediterranean Sea). *Pterois miles* (Scorpaeniformes, Scorpaenidae) was spotted for the first time in southern Laconia in summer 2019. The record of *Diadema setosum* (Diadematoida, Diadematidae) in summer 2019 in southern Laconia and Kythira Island represent the westernmost observations yet. The sightings of *Torquigener flavimaculosus* (Tetradontiformes, Tetradontidae) in the summers 2018/2019 confirm the presence of this species in the southern Peloponnese and represent the northwesternmost published record. The single individual of *Abudefduf vaigiensis* (Perciformes, Pomacentridae) observed in summer 2018 in Avlemonas harbour (Kythira Island) links the observations from western Italy and Malta to those from the Levant. The records of *Stephanolepis diaspros* (Tetradontiformes, Monacanthidae) from Elafonisos Island and *Enchelycore anatina* (Anguiliformes, Muraenidae) from southeastern Messenia and southern Laconia add to regional records of these taxa.

Counting of adult and juvenile *Siganus* spp.

With *Siganus luridus* (Perciformes, Siganidae) already being common in the early 2000s in the southern western Peloponnese (Bardamaskos *et al.* 2008) and with *S. luridus* being ubiquitous for the last few years (own observations), many large schools of juvenile and/or adult individuals of both species can be observed during diving excursions.

The numbers of adult *S. rivulatus* and juvenile *S.* cf. *luridus* in Figure 3 were strongly underestimated in the field and on underwater images. Actual counts reveal a minimum of at least 415 adult individuals and at least 1480 juvenile individuals. However, it needs to be remarked that both photographs did not catch the entire observed schools, indicating that the actual numbers were still considerably higher. The small size of the juveniles of about 4 to 5 cm in length suggests an age of less than one year (Bilecenoğlu and Kaya 2002).

Stephanolepis* cf. *diaspros Fraser-Brunner, 1940

In the afternoon on 29 July 2014, one individual of *Stephanolepis diaspros* (Figure 4) was encountered in a cove between algae-covered rocks near Lefki Beach, Elafonisos Island (36.476469°N / 22.983372°E) in about 2 m depth over sandy substrate among algae. Since the individual was positioning itself with the posterior towards the camera and trying to hide, a lateral shot of the entire body was impossible to achieve. Meristic counts therefore remain incomplete: first dorsal fin ray I, dorsal fin rays 29, anal fin rays 29 or 30, caudal fin rays I+10+I. Observable morphological features include a laterally compressed body with a pointed beak, lateral outline slightly concave between snout tip and the eye,

anterior dorsal fin consist of a single strong spine with a convex posterior skin flap (but not barbs as in some other descriptions), positioned above the posterior eye margin, second dorsal fin ray lengthened to a filament, second dorsal fin opposite to anal fin, absent pelvic fin, rough skin due to small erect, delicate spines branching in minute spinules, the latter present on the dorsal spine.

Figure 4. The reticulated filefish *Stephanolepis diaspros* near Lefki beach (Elafonisos Island, Laconia) in ca. 2 m depth, July 2014

Enchelycore anatina (Lowe, 1839)

A single individual of the fangtooth moray *Enchelycore anatina* (was observed in July 2015 on the rocky coast near the village of Archangelos on several days hiding in a crevice in about 2 m water depth during the daytime. The observed individual (Figure 5) featured morphological traits characteristic of the species following Ben-Tuvia and Golani (1984), Böhlke (2002) and compares well to other records from the Mediterranean (Lipej *et al.* 2011; Guidetti *et al*. 2012; Pirkenseer 2013a).

Observable morphological features include large, variably-sized brown and yellow blotches or irregular stripes (body), yellow lower jaw, small jaw pores, comparatively slender, pointed, light-brown head dappled with small yellow spots, gape flange reaching far behind the eye, concave upper jaw (gaping when the mouth is closed), glassy, elongated teeth (varying sizes and in several rows), long tubular anterior nostrils.

Since the individual did not entirely exit its hiding place, the total length could not be estimated but should be similar to the lengths (73–91 cm) cited in Ben-Tuvia and Golani (1984).

Figure 5. The fangtooth moray eel *Enchelycore anatina*
a: An individual north of Kalamaki beach (south of Koroni, Messinia), length close to 1.5 m in ca. 2.5 m depth, August 2015, **b:** a juvenile individual south of Amoudi beach (south of Koronid, Messinia), height of head ca. 2 cm in ca. 0.5 m depth, August 2014, **c:** a small, possibly subadult individual, south of Amoudi beach in ca. 1 m depth, August 2015, **d:** an adult individual near Archangelos (southern Laconia), length > 1 m in ca. 2 m water depth, July 2015, **e:** Individual in co-habitation with *Muraena helena* north of Kalamaki beach August 2015, length > 1 m in ca. 4 m depth, observed simultaneously as the individual in **a**.

In addition to the first sighting of *E. anatina* near Kalamaki Beach south of Koroni (Messinia) in summer 2013, additional individuals were sighted (Table 2). The fully-grown, large individuals in Figure 5a and/or 5e possibly represent a second sighting of the individual encountered in 2013 (Pirkenseer 2013a).

Table 2. Records of *Enchelycore anatina*. Number of individuals, date, time and estimated depth of first observation (I = number of individuals).

Survey area	Georeference	I	Date / time	Depth
South of Amoudi Beach (Messenia)	Approx. 36.75032°N / 21.91790°E	1	13.08.14 / 16:16	≈ 0.5 m
South of Amoudi Beach (Messenia)	Approx. 36.75032°N / 21.91790°E	1	10.08.15 / 9:35	≈ 1 m
North of Kalamaki Beach (Messenia)	36.74570°N / 21.90943°E	2	12.08.15 / 16:00	≈ 2.5 / 3.5 m
Archangelos	36.62905°N / 22.87623°E	1	29.07.15 / 18:04	≈ 2 m

Torquigener flavimaculosus Hardy & Randall, 1983

Several individuals of *Torquigener flavimaculosus* (Figure 6) were encountered in the summer months of 2018-2019 in shallow waters at three localities near the beach line on Elafonisos Island (Table 3). The differences in coloration patterns suggest the presence of four individuals. While the individuals observed in summer 2018 were single, a pair was recorded on 8 July 2019 (Figure 6).

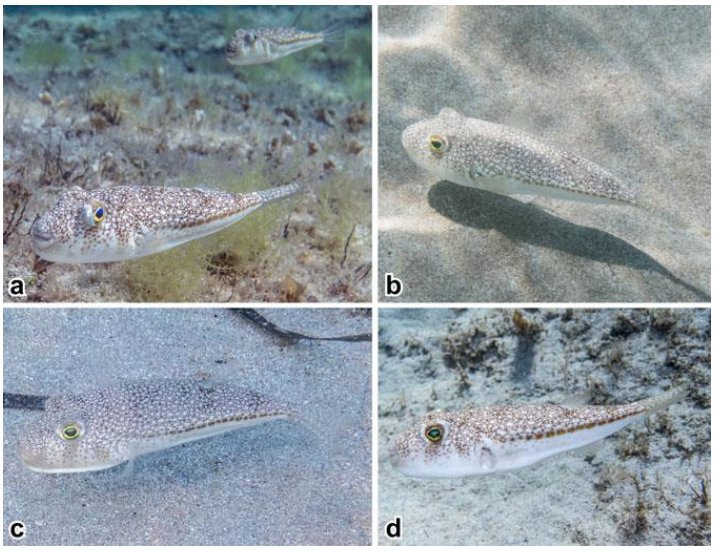


Figure 6. Individuals of *Torquigener flavimaculosus*
a: Elafonisos Island south coast in ca. 1.5 m depth, August 2019, **b:** Elafonisos village beach in ca. 0.8 m depth, July 2018, **c:** Elafonisos Panagia beach in ca. 0.5 m depth, August 2018, **d:** Elafonisos south coast in ca. 1.5 m depth, August 2019.

Table 3. Records of *Torquigener flavimaculosus*. Number of individuals, date, time and estimated depth of first observation (I = number of individuals).

Survey area	Georeference	I	Date / time	Depth
Elafonisos: Village beach	36.51017°N / 22.97355°E	1	30.07.18 / 19:18	≈ 0.5-1 m
Elafonisos: Panagia beach	36.48956°N / 22.94279°E 36.49046°N / 22.94356°E	1 1	01.08.18 / 13:27 08.08.19 / 18:45	≈ 0.3-1 m
Elafonisos: South coast	36.47652°N / 22.95836°E	2 1	07.08.19 / 17:20 08.08.19 / 16:30	≈ 1.5 m

Observed morphological features conform to Hardy and Randall (1983) and include the counts of seven anal and nine dorsal fin rays, a white belly, short, inconspicuous spines visible on the belly and the cheeks between the snout and the front of the pectoral fin, a network of fine brown lines encircling white spots on the dorsal side, small light brown dots on the cheeks, a row of the larger light brow to brown-orange dots stretching from the behind the upper base of the pectoral fin to the front of the caudal fin, nasal organ a short erect papilla *sensu* Hardy (1983), corner of mouth about level with upper pectoral-fin base, maximum eye diameter 8.8% of TL, pupil diameter 4.1% of TL. Distinct brown bands on the cheek *sensu* Hardy and Randall (1983) and pale-yellow zone following the mid-lateral row of lateral yellow-orange spots *sensu* Corsini-Foka *et al.* (2006) were not developed in the observed individuals.

Abudefduf vaigiensis (Quoy & Gaimard, 1825)

A single individual of sergeant-major (Figure 7) similar in appearance to the Indo-Pacific *Abudefduf vaigiensis* was encountered in the early evening around 19:00 on 3 August 2018 near the western entrance of Avlemonas harbour (36.22470°N / 23.08089° E) over the rocky bottom in turbulent waters due to wave action.

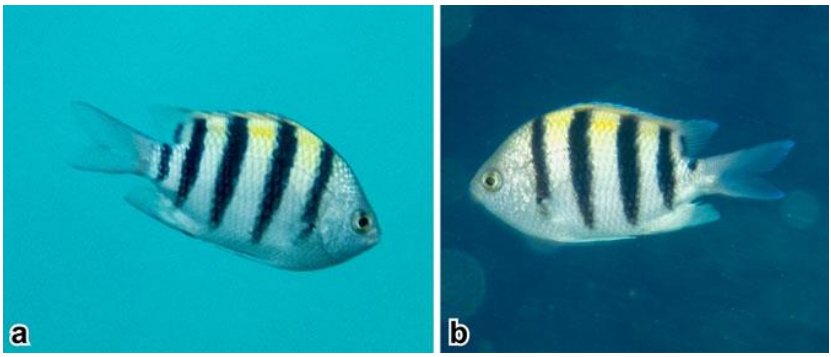


Figure 7. Individuals of *Abudefduf vaigiensis* near the Avlemonas harbour entrance, August 2018, note the incompletely developed fifth black bar on the left side. **a:** right lateral view, **b:** left lateral view.

The individual featured a pointed oval lateral outline, silver belly, yellow dorsal body, five vertical black bars on the right body side, with the fifth bar extending with a gap on the posterior margin of the dorsal fin. Four black bars are developed on the left side, with an incomplete fifth bar on the posterior margin of the dorsal fin and the anterior upper part of the caudal peduncle.

Pterois miles (Bennett, 1828)

The lionfish *Pterois miles* was encountered for the first time in southern Laconia and Kythira Island at the end of July 2019 (Table 4; Figure 8). In all localities, most the individuals hid during daytime under rocky overhangs. At Archangelos "East" one individual hovered over a *Posidonia* patch in open water around 16:00 in the afternoon, occasionally joined by a second individual. All observed individuals were adults.

Table 4. Records of *Pterois miles*. Number of individuals, date, time and estimated depth of first observation (I = number of individuals).

Survey area	Georeference	I	Date / time	Depth
Archangelos West	36.62894°N / 22.87544°E	3	23.07.19 / 16:45	≈ 3.5 m
Archangelos East	36.62952°N / 22.87663°E	4	24.07.19 / 16:22	≈ 2.5-4 m
Kythira: East of Palaeopoli beach	36.22501°N / 23.07535°E	1	31.07.19 / 9:29	≈ 2 m

The meristic and morphological interpretation follows Schultz (1986), confirming the presence of *P. miles* in Archangelos and near Avlemonas on Kythira Island. Meristic counts (Table 5) were carried out on images taken within a narrow time frame to avoid double counts of individual individuals.

Figure 8. Individuals of *Pterois miles* in July 2019
a: Archangelos transect west (southern Laconia) in ca. 3.5 m depth,
b: Overhang on rocky shore, with individual sitting upside-down, transect east of Palaeopoli beach (Kythira Island) in ca. 2 m depth.

Table 5. Meristic counts of five individuals of *Pterois miles* based on the observation and images taken on 24.07.2019 in Archangelos West around 16:13, in Archangelos East around 16:22, Kythira near Palaeopolis Beach on 31.07.2019 around 9:29.

Locality	Anal spines	Anal rays	Dorsal spines	Dorsal rays
Archangelos W	III	6	XIII	10
Archangelos W	III	6	XIII	10
Archangelos E	III	6	XIII	10
Archangelos E	III	6	XIII	10
Kythira	III	6	XIII	10

Diadema setosum (Leske, 1778)

Both observed individuals of *Diadema setosum* (Figure 9) adhere to the morphological characteristic summarized in Yokes and Galil (2006) and Bronstein and Kroh (2018). Spine length was about at least 1.8 times the test diameter for the larger individual from Avlemonas and about 2.5 times for the smaller individual from Archangelos. Both individuals featured the five characteristic white spots on the interambulacrum and the orange ring on the periproctal cone.

Table 6. Records of *Diadema setosum*. Number of individuals, date, time and estimated depth of first observation (I = number of individuals).

Survey area	Georeference	I	Date / time	Depth
Archangelos	36.62896°N / 22.87640°E	1	23.07.19 / 17:01	≈ 2.0 m
Avlemonas: harbour	36.22539°N / 23.08109°E	1	27.07.19 / 17:42	≈ 2.5 m

During daytime, the individual from Archangelos (Table 6) was observed for four days always resting in the same spot at the base of the rocky cliff, whereas the individual in Avlemonas harbour hid in a shaded crevice.

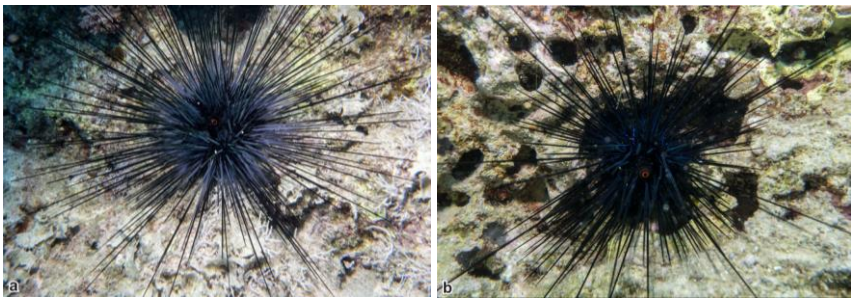


Figure 9. Individuals of *Diadema setosum* in July 2019
a: Avlemonas harbour (Kythira Island) in ca. 2.5 m depth, **b:** Archangelos (southern Laconia), departure point of transects in ca. 2 m depth.

Discussion

Morphology

The specific morphological criteria for *D. setosum* and *E. anatina* are well-defined. Recent information on the other four taxa based on new field studies and individual observations, as well as genetic studies, disclosed taxonomical uncertainties that are outlined below.

Stephanolepis diaspros
Morphology and estimated size for the individual of *S. diaspros* from Lefki Beach on Elafonisos Island conforms to general descriptions and images of observed Mediterranean individuals of *S. diaspros* (e.g. Golani *et al.* 2002; Ben Amor and Capabé 2008). The number of dorsal spines in the Atlantic species *Stephanolepis hispidus* and resembling *S. setifer* has been given as two in Berry and Voegele (1961), in contrary to one spine in *S. diaspros*. The second dorsal spine apparently is inconspicuous, since it cannot be distinguished on the figures provided in Berry and Voegele (1961) and available images of supposedly western Atlantic individuals (e.g. www.fishbase.org, Froese and Pauly 2019).

The development of a characteristic coloration pattern remains inconclusive between these three species, which has already been remarked by Ben Amor and Capabé (2008). While the individual from Elafonisos displayed some lozenge-shaped dark patches separated by whitish striations supposedly characteristic of *S. diaspros*, its overall colour pattern is rather blotched. A consistently predominant lozenge-shaped colour pattern for *S. diaspros* is not supported by published images (e.g. Dulčić and Pallaoro 2003; Giakoumi 2012; Balistreri and Parasporo 2015; Deidun *et al.* 2015; Iglesias and Frotte 2015; Mannino *et al.* 2016; Zenetos *et al.* 2017). The rather vermiculate colour pattern illustrated in previous studies, e.g. in Fischer *et al.* (1987), Bariche (2012) or Psomadakis *et al.* (2015), is also developed in the individual of *Stephanolepis setifer* figured in Berry and Voegele (1961). Two dark bands on the caudal fin exist in all three species, though their distinctness varies between individuals.

Torquigener flavimaculosus
Torquigener hypselogeneion (Bleeker, 1852) strongly resembles *T. flavimaculosus*. The neotype chosen for the former species by Hardy (1983), however, represents a very small individual (just 35 mm SL). The other individuals cited in Hardy (1983) do not exceed 63 mm SL, characterizing *T. hypselogeneion* as a small species. *Torquigener flavimaculosus* reaches 99 mm SL in the Red Sea (paratype in Hardy and Randall 1983), 111 mm (Corsini-Foka *et al.* 2006) to 144 mm (Sabour *et al.* 2014) SL, comparable to the size estimates for the individuals observed on the coast of Elafonisos Island. The larger *Torquigener florealis* (Cope, 1871) *sensu* Hardy (1983) is quite similar in coloration pattern to the individuals from Elafonisos Island, though the rosettes

of smaller brown spots are much less developed.

Since *T. hypselogeneion* occurs from southern Africa to Samoa (Hardy 1983), *T. florealis* in the Pacific and *T. flavimaculosus* in the western Indian Ocean, the Red Sea, the Persian Gulf, eastern Africa and the Seychelles (*sensu* www.fishbase.org, Froese and Pauly 2019), all records from the Mediterranean agree on the presence of *T. flavimaculosus* rather than *T. hypselogeneion*. The records from Elafonisos Island are attributed to the former species. Molecular analysis will clarify the taxonomical status in the future.

Abudefduf vaigiensis
The Indo-Pacific sergeant major *A. vaigiensis* and the sergeant-major *A. saxatilis* (Linnaeus, 1758) represent two morphologically closely related taxa. Tsadok *et al.* (2015) conclude that all Mediterranean individuals are genetically distinct from individuals sampled in the Red Sea. They even suggest that all records of *A. vaigiensis* from the Mediterranean based on morphological traits might pertain to misidentifications of *A. saxatilis*. Bariche *et al.* (2015) and Vella *et al.* (2016) however confirmed the presence of *A. vaigiensis* by barcoding individuals from the coast of Lebanon and Malta. Tsadok *et al.* (2015) also discuss the possibility of interbreeding of these closely related taxa, mixing up morphological traits similar to genetic alterations of the endemic *Abudefduf abdominalis* in Hawai'i (Coleman *et al.* 2014). Since the co-occurrence of both species has been proven in Maltese waters (e.g. Vella *et al.* 2016), interbreeding may have taken place.

Tsadok *et al.* (2015) and others (e.g. Azzurro *et al.* 2013; Vella *et al.* 2016) consider the two black spots on the caudal peduncle following the fifth black bar and a gapless extension of the fifth vertical black bar to the posterior end of the dorsal fin as characteristic of *A. saxatilis*. These spots and the gapless extension of the fifth black bar were not observed in the individual from Kythira Island, allowing a determination as *A. vaigiensis*.

Pterois miles
According to Schultz (1986), *P. miles* and *P. volitans* are very similar except for the meristic counts of the anal and dorsal spines and fin rays. Furthermore, larger individuals of *P. volitans* on average tend to feature correspondingly longer pectoral fins and larger spots on the vertical fin than *P. miles*. Meristic counts and general morphology attribute the individuals from Archangelos and Kythira Island to *P. miles*.

Distribution in the Mediterranean

Diadema setosum
The first record of *D. setosum* in the Mediterranean hails from the Kaş Peninsula (southwestern Turkey) in 2006 (Yokes and Galil 2006) (Figure 10). Yokes and Galil (2006) speculate on the mode of introduction via larval migration through the Suez Canal, ship transport or release from aquaria, since the first record was

made at about 600 km linear distance north of the mouth of the Suez Canal. Since the development of the competent larval (capable of settling on the seafloor) stage occurs around 35 days post-fertilization (Aminur Rahman *et al.* 2015), larvae are potentially suspended long enough to reach southwestern Turkey with cyclonic surface currents of the Levantine (Millot and Taupier-Letage 2005), e.g. Cilician and Asia Minor currents of up to and above 30 cm/sec (Gerin *et al.* 2009; Poulain *et al.* 2012) before settling to the sea-floor (a journey of roughly 1300-1500 km).

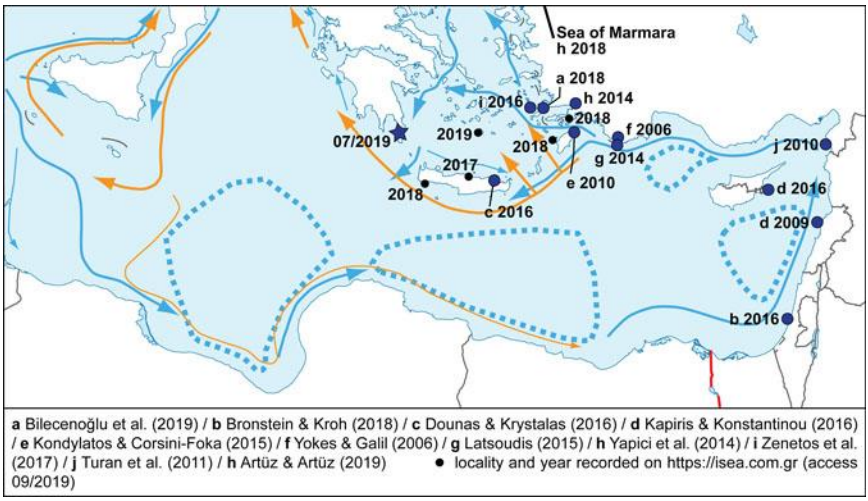


Figure 10. Distribution of *Diadema setosum* in the Mediterranean.
The most recent westernmost occurrences hail from Archangelos (Laconia) and Avlemonas (Kythira Island) from July 2019. Colour of circles conforms to species code in Figure 2 and denotes published reports, star denotes observation area of this paper. Blue lines = surface currents of the modified Atlantic water (MAW), orange lines = currents of the deeper Levantine intermediate water (LIW); thick lines = main currents, thin lines = secondary / seasonal currents, stipled lines = areas of current instabilities (currents patterns simplified from Millot and Taupier 2005).

Therefore, the first record of this species from south-western Turkey before other sightings closer to the northern exit of the Gulf of Suez seems plausible, that is, not counting the unknown traversal time of larvae from the Gulf of Suez to Port Said. It has also been argued that the findings near port areas may pertain to transport of larvae by recreational boats (Kondylatos and Corsini-Foka 2015). Introduction via the Suez Canal and a subsequent larval drift seems to be the most likely mode of dispersal since there are no records of *D. setosum* west of Port Said and the latest and westernmost occurrences hail from Laconia and Kythira Island (this paper) in summer 2019 (Figure 2).

Abundances of *D. setosum* in the Red Sea reach up to more than 30 individuals per square meter on live corals, whereas in habitats like seagrasses, rocks and sand common for the Mediterranean abundances were much lower with maximum occurrences of 3.8, 7.8 and 2.3 individuals per square meter (Hasan

2019). The single individual records in the Mediterranean including the observation area indicate either an initial, pioneering settling situation with yet non-reproductive population densities or the unsuitability of the local substrate/environment to substitute larger populations.

Torquigener flavimaculosus

Similar reasoning of larval transport may be applied to the early record pattern of *T. flavimaculosus*, with the first record stemming from Israel in 1987 (Golani 1987) (Figure 11). The subsequent records hail from southwestern Turkey in 2003 (Bilecenoğlu 2003) and Rhodos Island in 2006 (Corsini-Foka *et al*. 2006). Records closer to the suspected "source" of the species (e.g. from Syria, Lebanon, Cyprus; 2008-2011) occur between the observation in southwestern Turkey and the numerous records in the southern Aegean and the Ionian Sea form 2016 onwards. The delayed clockwise range expansion (2015-2017) along the Egyptian and Libyan coast - despite being geographically closer to Port Said - may be explained through settling by subadults and adults against the prevailing surface currents rather than larval drift.

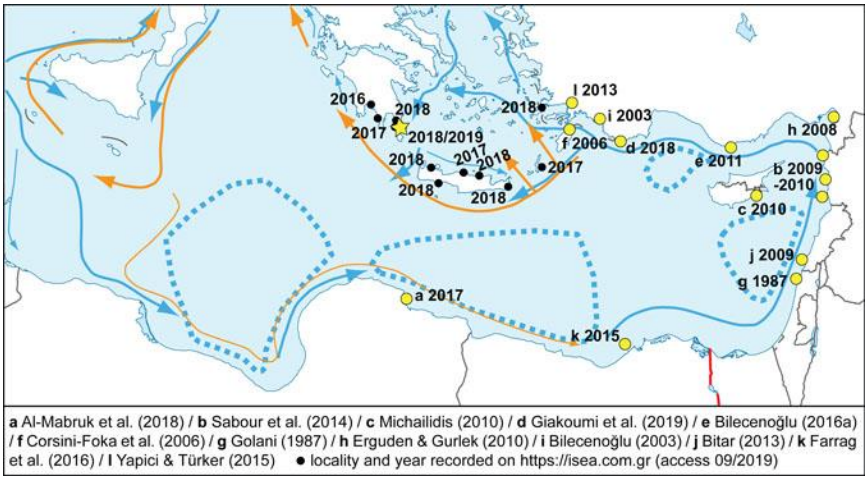


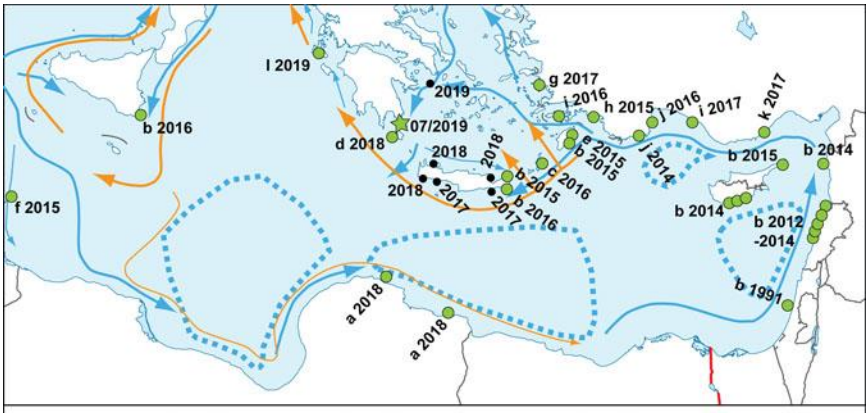
Figure 11. Year end 2019 distribution map of *Torquigener flavimaculosus* in the Mediterranean.

Colour of circles conforms to species code in Figure 2 and denotes published reports, star denotes observation area of this paper. Blue lines = surface currents of the modified Atlantic water (MAW), orange lines = currents of the deeper Levantine intermediate water (LIW); thick lines = main currents, thin lines = secondary / seasonal currents, stipled lines = areas of current instabilities (currents patterns simplified from Millot and Taupier 2005).

Pterois miles

A gap of 21 years lies between the first record of *Pterois miles* in Israel and Lebanon. The subsequent succession of first records of *P. miles* in the Levant and Greece shows a rapid anticlockwise spread of the species (Figure 12), with many

sightings derived from the southern and southeastern Turkish coast between 2014 and 2017 (e.g. Turan and Öztürk 2015, Özbek *et al.* 2017, Yapıcı 2018). The first records from Tunisia (Ben Amor and Ghanem 2016) in 2015 and eastern Sicily in 2016 (Azzurro *et al.* 2017) before the records on the Libyan coast (Al-Mabruk and Rigalla 2019) and Greece remain puzzling. The northernmost record so far hails from Cephalonia Island (W Greece; Vavasis *et al.* 2019).



a Al-Mabruk & Rigalla (2019) / **b** Azzurro et al. (2017) / **c** Poursanidis & Marakis (2016) / **d** Mitsou & Maximiadi (2018) / **e** Corsini-Foka & Kondylatos (2015) / **f** Ben Amor & Ghanem (2016) / **g** Yapici (2018) / **h** Turan & Öztürk (2015) / **i** Bilge et al. (2016) / **j** Özgür Özbek et al. (2017) / **k** Yağlıoğlu and Ayaş (2016) / l Vavasis et al. (2020) ● locality and year recorded on https://isea.com.gr (access 01/2020), list not complete (only westernmost occurrences)

Figure 12. Distribution map of *Pterois miles* in the Mediterranean.
Colour of circles conforms to species code in Figure 2 and denotes published reports, star denotes observation area of this paper. Blue lines = surface currents of the modified Atlantic water (MAW), orange lines = currents of the deeper Levantine intermediate water (LIW); thick lines = main currents, thin lines = secondary / seasonal currents, stipled lines = areas of current instabilities (currents patterns simplified from Millot and Taupier 2005).

Abudefduf vaigiensis

The situation for *Abudefduf vaigiensis* is much less clear-cut since records are scarce and widely distributed in the Mediterranean (Figure 13). In fact, the first record of *A. vaigiensis* hails from Naples in 1957 (Tardent 1959). Tardent (1959) considers a transport via ship ballast or similar modes of transport as a likely provenance of the single encountered individual, as may be the case for the record from Genoa in 2000 (Vacchi and Chiantore 2000). The observation of an individual on the coast of northern Israel in 1997 (Goren and Galil 1998) probably relates to migration via the Suez Canal. The subsequent few records from Lebanon (2012), Cyprus (2018) and the Kythira Island (2018) hint at a dispersal assisted by the Levantine currents similar to *D. setosum* and *P. miles*.

So far, the easternmost record of the morphologically similar Atlantic species *Abudefduf saxatilis* hails from Israel (Tsadok *et al.* 2015) and western Turkey (Bilecenoğlu 2016b), with a large geographic gap to the record from Malta (Deidun and Castriota 2014).

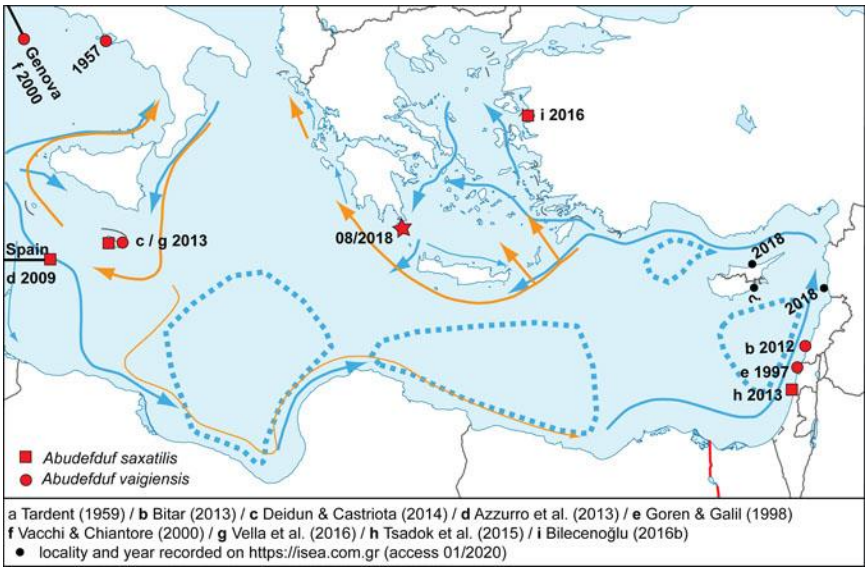


Figure 13. *Abudefduf vaigiensis and A. saxatilis* in the Mediterranean. Colour of circles conforms to species code in Figure 2 and denotes published reports, star denotes observation area of this paper. Blue lines = surface currents of the modified Atlantic water (MAW), orange lines = currents of the deeper Levantine intermediate water (LIW); thick lines = main currents, thin lines = secondary / seasonal currents, stipled lines = areas of current instabilities (currents patterns simplified from Millot and Taupier 2005).

Enchelycore anatina

The allopatric distribution of *Enchelycore anatina* in the Atlantic and the eastern Mediterranean (Ben-Tuvia and Golani 1984; Ben Rais Lasram *et al.* 2008; Pirkenseer 2013a) remains puzzling. The most plausible mode of dispersal is the modified Atlantic water (MAW) and the mid-Mediterranean jet (MMJ) along the North African coast (Pirkenseer 2013a), but thus far this species has not been recorded from this area and the entire western Mediterranean basin. Its early sightings show a rather random distribution (Figure 14): Israel in 1979 (Ben-Tuvia and Golani 1984), Elafonisos Island in 1987 (Golani *et al.* 2002) and southwestern Turkey in 1998 (Erguden *et al.* 2013). The subsequent records also do not follow a clear dispersal pattern. The low frequency of sightings is most likely due to its cryptic and solitary lifestyle. Co-habitation with *Muraena helena* was observed near Kalamaki Beach (Messinia, Greece) in summer 2015 during daytime (Figure 4e). The strong increase of sightings during the last few years especially on Cretan coasts hints at an establishment of a reproductive population of *E. anatina*. A small juvenile individual (Figure 4b) was observed in summer 2014 south of Amoudi Beach (Messinia).

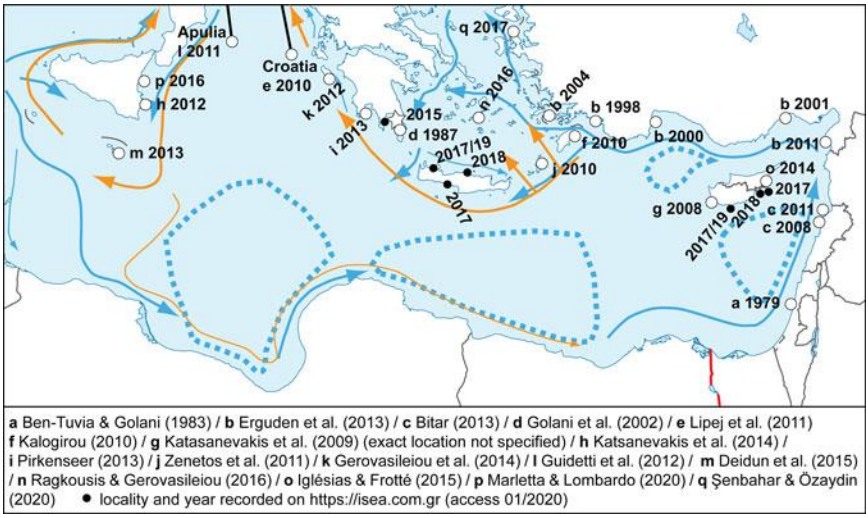


Figure 14. *Enchelycore anatina* in the Mediterranean.
Colour of circles conforms to species code in Figure 2 and denotes published reports, star denotes observation area of this paper. Blue lines = surface currents of the modified Atlantic water (MAW), orange lines = currents of the deeper Levantine intermediate water (LIW); thick lines = main currents, thin lines = secondary / seasonal currents, stipled lines = areas of current instabilities (currents patterns simplified from Millot and Taupier 2005).

Perspectives

Of the recorded six species stated in this paper, all have at least reached the southern Peloponnese, with *S. diaspros*, *P. miles* and *E. anatina* having been documented further north and west in the Adriatic Sea and Malta, Tunisia and/or eastern Sicily. *A. vaigiensis* records are still too scattered and scarce to draw any conclusions.

The records of *D. setosum* from Archangelos (Laconia) and Kythira Island in summer 2019 represent the westernmost occurrences yet. The continued presence of *T. flavimaculosus* on Elafonisos Island confirms its presence in the southern Peloponnese indicated by the previous records on the iSea webpage since 2016.

The sudden appearance of *P. miles* in Archangelos in summer 2019 with at least seven adult individuals indicates a fast establishment of a potentially reproductive population of this overall sedentary (Fishelson 1997) species in the area. *P. miles* seems to be spreading further north-westward (see also the record of *P. miles* from Cephalonia Island) into potentially suitable habitats as predicted in Poursanidis *et al.* (2020) and a potential niche expansion hotspot *sensu* Parravicini *et al.* (2015).

The encounters with *E. anatina* individuals, including a juvenile in the years 2013 to 2015 seemed to indicate a continued regional presence. Since 2015 however no further individuals have been sighted.

"Sample bias" should not be underestimated with single individual records, where conspicuous taxa both in appearance and behaviour are being observed and reported more often. Scale effects related to differences in observation efforts per region also contribute to the potential record bias. They contribute to the lag times of human responses (detection, publication lags) outlined in Azzurro *et al.* (2016), influencing the documentation of arrival, establishment and expansion of non-indigenous species. For the discontinuous or single sightings of *E. anatina* and *S. diaspros* "repeated" detection lags of non-schooling, comparatively rare taxa in the investigated area might be the cause. The single record of *A. vaigiensis* represents a stray individual of a normally schooling species.

Future surveys may verify the establishment and increase in numbers of *P. miles* and *D. setosum* in the southern Peloponnese. Establishment of both species pending, interactions with the indigenous environment may develop. Bilecenoğlu *et al.* (2019) reported several fish taxa, including *Chromis chromis* hiding between the spines of *Diadem setosum*, with Mediterranean *Pterois miles* preying upon this species (Giovos *et al.* 2018).

Symposia and workshops on alien species in the Mediterranean Sea (e.g. EastMed 2010, Langar and Ouerghi 2019) increased the public and scientific awareness of the Lessepsian migration and other modes of introduction of alien species as well as their impact on indigenous habitats. The growing familiarity of so-called citizen scientists with the topic of non-indigenous species (e.g. Zenetos *et al.* 2013) certainly contributes to the rapid increase of reports during the last few years published in papers and submitted to digital platforms (e.g. iSea, Oberservadores del mar). Additionally much more affordable and available underwater cameras facilitate documentation of biota during free-diving and scuba excursions. Overall the southern Peloponnese waters are rather underrepresented in published studies on non-indigenous species but feature comparatively numerous sightings submitted to social media (e.g. iSea).

The reports of the taxa presented in this paper provide additional data points for future studies refining pan-Mediterranean models dealing with non-indigenous species. Furthermore, local communities can be alerted to the presence and correct handling of potentially dangerous species like *P. miles*, or to initiate local countermeasures as removing individuals (especially sedentary ones like *D. setosum*) before establishment.

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