J. Black Sea/Mediterranean Environment
Vol. 29, No. 2: 167-184 (2023)

RESEARCH ARTICLE

New data on the spreading of the fangtooth moray *Enchelycore anatina* (Lowe, 1838) in the Mediterranean Sea

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Abstract

Fangtooth moray, *Enchelycore anatina* (Lowe, 1838), native to the tropical Atlantic Ocean, has a rapid expansion in the eastern and central sectors of the Mediterranean in the last thirty years. This species is now beginning to colonize along the Italian coasts of the Adriatic Sea and the western Mediterranean. In summer of 2021 and 2022, 12 specimens of fangtooth moray were recorded in Puglia (Adriatic Sea), Sardinia and Sicily. As hypothesized in previous studies, it seems probable that the successful expansion of this species is due both to the long pelagic period of its larval stage and to the increase in the temperature of the Mediterranean waters.

Keywords: *Enchelycore anatina*, Adriatic Sea, central Mediterranean, western Mediterranean

Received: 12.06.2023, **Accepted:** 18.09.2023

Introduction

The fangtooth moray, *Enchelycore anatina* (Lowe, 1838), is a fish species belonging to the Murenidae family, widespread along the eastern coasts of the Atlantic Ocean, between the Island of Sant'Elena to the south and the Azores Islands to the north (Golani *et al*. 2002). According to Zenetos *et al*. (2012), due to its origin, this species is considered as a species with an expanding range in the Mediterranean basin.

Ben-Tuvia and Golani (1984) reported the first capture of *E. anatina* by fishermen in 1979, off the coast of Israel at a depth of approximately 50 meters.

After that first report *E. anatina* has been reported many times at different sites in the eastern and central Mediterranean and in the Adriatic Sea (Marletta and Lombardo 2020).

Considering the high number of reports of the fangtooth moray made in recent decades in many locations in the Mediterranean and also taking into account that the first report of it for the Mediterranean Sea occurred from the Israeli coast, one could reasonably assume that *E. anatina* may have established stable populations in many areas along the Mediterranean coasts over all these years. In this study six specimens of *E. anatina* from the Italian coasts are reported; one from the coasts of Puglia; two from the waters of western Sicily and three new records from the western coasts of Sardinia.

In particular, the reports of *E. anatina* from western Sicily represent further confirmation that stable populations of this species are well present in the central Mediterranean. To this it must be added that the reports of *E. anatina* from the western coasts of Sardinia demonstrate how this species has permanently colonized the western Mediterranean and is therefore present in all biogeographical sectors of the Mediterranean basin.

Materials and methods

The observations reported in this paper were made in July and August of 2021 and 2022 during self-financed research activities.

The observations were conducted by scuba diving or in freediving depending on the depth of the seabed where the operation was carried out. The censuses were carried out with non-invasive methods and no specimens were ever collected physically. In fact, we proceeded with the visual census method, reporting the observations on underwater writing slates prepared for this purpose.

The choice of dive sites depended on the main activity that was the purpose of our study; that is, investigating the state of *Posidonia* meadows in relation to the presence of invasive alien plant species present in the monitoring sites, for example *Caulerpa* ssp. and *Acrothamnion preissii* (Sonder) E. M. Wollaston 1968.

Results

During the two monitoring campaigns (July and August 2021 and 2022), in total 12 specimens of *E. anatina* of sizes ranging approximately between 40 and 80 centimeters were recorded.

During the summer of 2021, three specimens of the fangtooth moray *E. anatina* were identified in the coastal waters of Puglia and Sardinia (Figure 1).

The first observation of *E. anatina* took place in July 2021 in Torre Canne near Brindisi, in Puglia (40° 51' 4.129" N; 17° 27' 9.953" E) during a monitoring study of alien species in the Posidonia bed (Figure 1b). Two specimens of fangtooth moray were observed inside a small fracture between the rocks of the seabed at a depth of 15 meters.

At the end of August 2021, a recreational diver encountered and photographed a specimen of *E. anatina* in Sardinia at a depth of 25 meters. The location where the observation was made is located in the northern limit of the Bay of Alghero (40° 34' 51.881" N; 8° 15' 54.885" E), along the western coast of Sardinia, in the western part of the Mediterranean basin (Figure 1a, Figure 2). In this area the seabed is mainly rocky with rich algal cover and offers numerous shelters for benthic fauna.

During July and August 2022, similar monitoring studies were carried out along the western coasts of Sardinia and Sicily (Figure 1).

In July 2022, three specimens of *E. anatina* were recorded during the monitoring study on the coasts of Sardinia. On 14 July 2022, two specimens of *E. anatina* were observed in a place called "Baia di Villa Assunta" (40°40'42.312"N; 8°11' 45.564"E), near Alghero (Figure 1a). The two moray eels were half-hidden among the rocks at a depth of about 9 meters on a seabed with dense algal cover.

On 16 July 2022, during the monitoring in the vicinity of "Isola di Mal di Ventre" (39°58'23.282"N; 8°23'19.651"E), a specimen of *E. anatina*, swimming, was identifed at a depth of 11 meters on the bottom, between the rocks and Posidonia bed.

During the second half of August 2022, visual census activities were carried out along the coasts of western Sicily, in south of the city of Trapani.

On 24 August 2022, during the monitoring in "Capo Granitola" (37°33'53.442" N; 12°39'44.629"E) two specimens of *E. anatina* hidden among the rocks on the edge of the Posidonia bed at a depth of 7 metres were observed. Besides, on 26 August 2022, during the visual census activity carried out near the town of Marsala (37°48'7.618"N; 12°25'25.366"E), a specimen was encountered near the rocky bottom intensely covered by green and brown algae.

On September 2022, three specimens of *E. anatina* were observed in Vendicari (36°49'6.092"N; 15°6'39.401"E) at the depth of 12 metres on a rocky bottom in the immediate proximity of a Posidonia bed with wide intermatte channels.

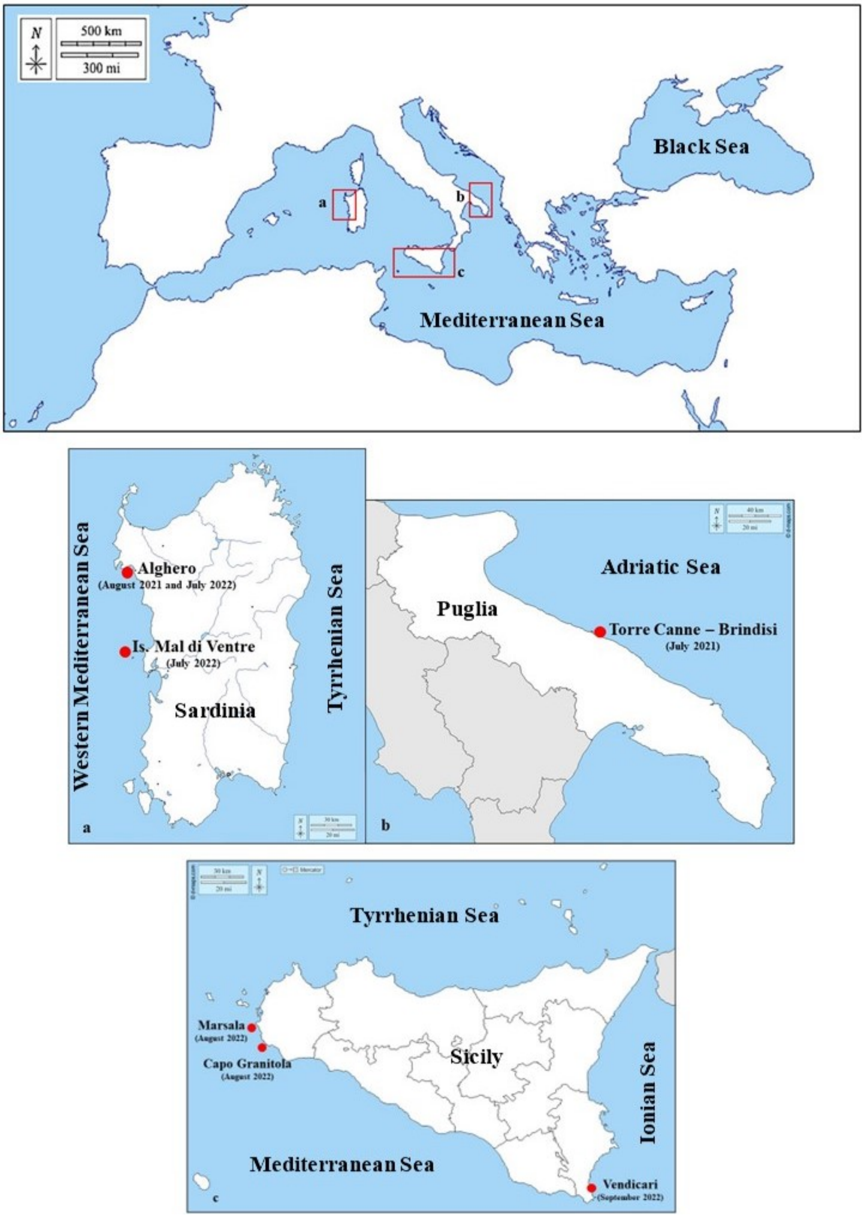

Figure 1. Locations where *Enchelycore anatina* observations were made: a - Sardinia; b - Puglia; c - Sicily

Figure 2a and b. Photographs of the specimen of *Enchelycore anatina* at the Bay of Alghero (Sardinia – Italy), with distinctive arched jaws, typical to this species

Discussion

The purpose of this study is to provide further information on the expansion of *E. anatina* in the Mediterranean. In fact, after the first report for the Mediterranean (Ben-Tuvia and Golani 1984), this species has been reported along the coasts of the Levantine Basin, Ionian Sea and Adriatic Sea. These reports are well summarized in Marletta and Lombardo (2020) and Tiralongo *et al*. (2020).

We agree with Tiralongo *et al*. (2020) who conclude that the abundance and presence of *E. anatina* in Mediterranean Basin is probably underestimated due to the behavioral habits of this species which spends most of its time inside the burrows. To this statement, we also add that *E. anatina*, like other moray eels, is not a coveted prey by small-scale coastal fishing operators. In fact, most moray eels caught with nets or longlines are (almost) always thrown back into the sea. It follows that the stocks of these species are greatly underestimated compared to the real number. Intrestingly, *E. anatina*, despite being a species native to the subtropical belt of the eastern Atlantic Ocean, has extended their distribution constantly in the Levantine basin of the Mediterranean and only after a few years made its appearance in the Aegean Sea and then spread to the Ionian and Adriatic Seas. This phenomenon has been explained by various factors. One of them is that the superficial Atlantic currents entering the Mediterranean have pushed the eggs, larvaes and propagules of the Atlantic species towards the eastern sectors of the Mediterranean along the coast of North Africa (Albérola and Millot 1995; Lasram *et al*. 2009).

Other factor suggested by Golani *et al*. (2006) and Guidetti *et al*. (2012) is that *E. anatina* has a long period of larval development. Therefore, the surface currents play a fundamental role in allowing this fangtooth moray to colonize very distant ranges from their places of origin.

Another factor that seems to influence the colonization of the Levantine basin by *E. anatina* is the average temperatures of the waters in that part of the Mediterranean during the year. In fact, in that basin of the Mediterranean the climatic factors are very similar to those ranges typical to the origin of this moray (Wolf *et al*. 1998; Duncan *et al*. 2001). The climatic factor, therefore, could have positively influenced the possibility that the first specimens of this species had settled in those areas and from there, subsequently, the colonization of the central and eastern part of the Mediterranean began and then expanded also towards the Adriatic (Lasram *et al*. 2009).

In addition to these "natural factors", there is at least one of anthropic origin linked to the transport of the eggs and larvae of *E. anatina* in the ballast waters of the numerous merchant ships that arrive daily in the large commercial port of Porto Torres, in the north-west of Sardinia.

Ballast water transport has already been demonstrated for other Mediterranean non-indigenous species such as *Aplysia dactylomela* Rang, 1828 (Valdés *et al*. 2013; Crocetta and Galil 2012) and Atlantic tripletail *Lobotes surinamensis* (Bloch 1790) (Riera *et al*. 1999; Fischer *et al*. 1987; Camilleri *et al*. 2005; Tiralongo *et al*. 2019). But, we believe that the most striking example of this diffusion model of a NIS in the Mediterranean is represented by *Callinectes sapidus* (Rathbun, 1896). *C. sapidus*, in fact, arrived in the port of Trieste with the ballast water of ships from the USA and spread throughout the Mediterranean basin and the Black Sea (Mizzan 1993; Mancinelli *et al*. 2021; Ragkousis *et al*. 2023; Yaglıoglu *et al*. 2014).

In consideration of what we have observed and of the hypotheses formulated by the cited authors, we believe we can assert that the presence of *E. anatina* in the waters of western Sardinia can be explained by the synergistic action of the above dispersion methods.

For this reason we believe that further studies and monitoring should be conducted in order to have increasingly reliable data on the real consistency of the stocks of *E. anatina* present not only in Sardinia but also in the Mediterranean and in the Black Sea.

In our opinion, all this can be achieved through an adequate action to raise awareness among small-scale coastal fishing operators and underwater fishermen. In our opinion, in fact, these categories of "citizen scientists", above all the last one, are the ones who, better than others, can provide valid data on the real dimensions of the stocks of the target species in the monitoring activities. (Sbaraglia *et al*. 2023 with all supplementary material and cited literature).

Suplemental material: Table 1: Summary table of reports of *E. anatina* (Lowe, 1838) in the Mediterranean Sea with bibliographic references.

Aknowledgement

The authors are very grateful to Mr. Celestino Papi for sharing the information and images of *Enchelycore anatina* and the two anonymous reviewers for valuable suggestions and topics for reflection.

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Table 1. Chronologically listed summary table of *E. anatina* (Lowe, 1838) reports from the Mediterranean Sea

Number of record	Location name	Latitude (N)	Longitude (E)	Year of observation	Number of specimens	Depth (m)	Habitat	Reference
1	Tel Aviv	32,0864	34,7688	1979	1	50	x	Ben Tuvia and Golani 1984
2	Elafonissos Island	36,5086	22,9802	1987	5	x	x	Golani *et al*. 2002
3	Fethiye Bay	36,6589	29,1084	1998	1	x	x	Altan 1998
4	Antalya Bay	36,8832	30,6804	2000	1	x	x	Yokes *et al*. 2002
5	Mersin coast	36,7952	34,6319	2001	2	10	x	Can and Bilecenoglu 2005
6	Datca Peninsula	36,7257	27,6866	2004	1	x	x	Okuş *et al*. 2004
7	Coast of Syria	35,238	35,9214	2005	x	x	x	Saad 2005
8	Island of Bisevo	42,9817	16,0195	2007	1	12	steep rocky wall covered with algal vegetation and with many holes	Lipej *et al*. 2011
9	Coast of Cyprus	34,718	33,3849	2009	1	x	x	Katsanevakis *et al*. 2009
10	Kolimbia Bay	36,2451	36,2451	13/04/2010	1	20-25	rocky bottoms	Kalogirou 2010
11	Hertliyya	32,1657	34,7922	05/05/2010	3	30	x	Lipej *et al*. 2011

Table 1. Continued

12	Island of Susac	42,7636	16,5025	24/07/2010	1	17	burrow on a vertical wall	Lipej *et al.* 2011
13	Haifa Bay	32,8174	35,0311	17/10/2010	1	8	x	Lipej *et al.* 2011
14	Iskenderun Bay	35,9597	35,9244	21/07/2011	1	12	rocky bottoms rich in crevices	Ergüden *et al.* 2013
15	Apulian coast	39,8867	18,3977	4 and 30/08/2011	2	6	rocky bottom rich in crevices and holes, with a sciaphilous assemblage	Guidetti *et al.* 2012
16	Bijelac Islet	42,6344	18,0733	22/09/2011	1	x	x	Dulčić *et al.* 2014
17	Plemmirio marine reserve	37,011	15,3062	May 2012	1	5	rocky bottom rich in crevices covered by a sciaphilous assemblage	Katsanevakis *et al.* 2014
18	National Marine Park of Zakynthos	37,701	20,939	09/08 and 03/11/2012	2	11-15	rocky crevices of large boulders	Kapiris *et al.* 2014
19	Kalamaki beach	36,7467	21,91	9 and 14/08/2013	2	3-4	boulders and blocks with an abundance of hiding spaces; isolated rock outcrop	Pirkenseer 2013
20	Island of Malta	35,9885	14,3274	Sep 2013	1	12	crevice within a gently-sloping aggregation of rocks and medium-sized	Deidun *et al.* 2015

Table 1. Continued

21	Agio Anargyroi	34,975	34,0769	21/09/2014	3	5-7.5	rocky hole; holes on a vertical wall of coralline seaweeds	Iglésias and Frotté 2015
22	Lopud Island	42,6666	17,95	Nov 2015	1	15	x	Bartulović *et al*. 2017
23	Karaburun (Central Aegean Sea, Izmir Bay)	38,6755	26,4714	July 2017	1	5	rocky bottoms in a crevice	Şenbahar and Özaydın 2020
24	Kyklades Archipelago	36,7475	25,367	3 and 29/06/2019	2	2-8	semi-submerged cave between boulders; crevice on a rocky slope	Dailianis *et al*. 2016
25	Phaselis	36,525	30,5539	03/06/2018	1	3-4	among the rock cracks	Teker *et al*. 2019
26	Aci Trezza (MPA Isole Ciclopi)	37,5615	15,1575	September 2016 to 2019 *	1	16	bedrock with algae	Marletta and Lombardo 2020
27	Santa Maria La Scala	37,6172	15,1722	June 2017	1	15	rocky bottom	Marletta and Lombardo 2020
28	Tremiti Islands	42.10603	15.48673	03/08/2019	1	15	x	Tiralongo *et al*. 2020
29	Punta Formiche (SR)	36,6711	15,0519	2020	1	3	rocky	Vincenzo Di Martino & Bessy Stancanelli in Ragkousis *et al*. (2023)

Table 1. Continued

30	Palma di Montechiaro (TP)	37,1933	13,6628	2021	2	5	rocky	Vincenzo Di Martino & Bessy Stancanelli in Ragkousis *et al*. (2023)
31	Capo Bianco (AG)	37,3887	13,2724	2021	1	3	rocky	Vincenzo Di Martino & Bessy Stancanelli in Ragkousis *et al*. (2023)
32	MPA Isole Ciclopi (CT)	37,5584	15,1616	2021	1	15	rocky	Vincenzo Di Martino & Bessy Stancanelli in Ragkousis *et al*. (2023)
33	Capo Campolato (SR)	37,2936	15,1994	2021	2	14	rocky	Vincenzo Di Martino & Bessy Stancanelli in Ragkousis *et al*. (2023)
34	Capo Santa Croce (SR)	37,2431	15,2579	2021	1	20	rocky	Vincenzo Di Martino & Bessy Stancanelli in Ragkousis *et al*. (2023)

Table 1. Continued

35	Kastellorizo Is. (Greece)	36,125726	29,578819	10/08/2020	3	21.5	marine cave semi-submerged	Markos Digenis & Michail Ragkousis in Ragkousis *et al*. (2023)
36	Falkonera Is. (Greece)	36,7862	24,636505	19/08/2020	2	4	marine cave semi-submerged	Markos Digenis & Michail Ragkousis in Ragkousis *et al*. (2023)
37	Tilos Is. (Greece)	36,4207	27,3346	13/08/2021	1	6	rocky reef	Eleni Kytinou in Ragkousis *et al*. (2023)
38	Crete Is. (Greece)	34,940671	25,051309	03/09/2021	1	1	rocky reef	Grigorios Skouradakis in Ragkousis *et al*. (2023)
39	Crete Is. (Greece)	35,198859	24,061003	22/09/2021	1	2	cave dark zone	Markos Digenis in Ragkousis *et al*. (2023)
40	Crete Is. (Greece)	35,417172	24,786907	19/08/2020	5	6	rocky bed	Panos Grigoriou in Ragkousis *et al*. (2023)
41	Kelibia (Tunisia)	36,82893	11,13571	31/05/2020	1	35	sandy bottom with seagrass	Raouia Ghanem in Ragkousis *et al*. (2023)

Table 1. Continued

42	Bomba Bay - Tobruk (Libya)	32,39259	23,13586	26/12/2020	1	20	rocky seabed	Ibrahim *et al*. 2022
43	Saline Ioniche (RC)	37,93433	15,71295	17/07/2020	1	10	rocky bed and Posidonia	Ibrahim *et al*. 2022
44	Grotta Azzurra	37,85158	15,30416	13/08/2017	1	24	rocky bottom	Perzia *et al*. 2022
45	Capo Taormina	37,84544	15,29586	5 - 12/09/2018	4	12	rocky bottom	Perzia *et al*. 2022
46	Isola Bella	37,84950	15,30086	28/08 and 17/09/2018	6	16	rocky bottom	Perzia *et al*. 2022
47	Torre Canne near Brindisi (Apulia - Italy)	40,8510	17,4528	22/07/2021	2	15	Posidonia bed	present paper
48	Alghero Bay (Sardinia Is.)	40,5811	8,2652	26/08/2021	1	25	rocky bottom with algae	present paper
49	Villa Assunta bay (Alghero - Sardinia)	40,6784	8,1960	14/07/2022	2	9	rocky bottom	present paper
50	Mal di Ventre Is. (MPA Penisola del Sinis e Isola di Mal di Ventre - Sardinia)	39,9731	8,3888	16/07/2022	1	11	rocky bottom with Posidonia	present paper
51	Capo Granitola	37,5648	12,6624	24/08/2022	2	7	rocky bottom with Posidonia	present paper
52	Marsala	37,8021	12,4237	26/07/2022	1	8	rocky bottom with algae	present paper
53	Vendicari	36,8184	15,1109	03/09/2022	2	12	rocky bottom	present paper