

MARINE RECORD

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Occurrence of the Smallscale Codlet, *Bregmaceros nectabanus* in the Mediterranean Sea, previously misidentified as *B. atlanticus* in this region

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Abstract

Background: We report the occurrence of *Bregmaceros nectabanus* as the only species of this genus occurring in the Mediterranean Sea.

Results: All previously published records of *B. atlanticus* from the Mediterranean are based on misidentifications. Among the features that distinguish *B. nectabanus* are its nearly unpigmented abdomen, presence of a thin dorsolateral longitudinal stripe below the second dorsal fin, and a distally fimbriate opercular spine.

Conclusions: Since this species is known also from the Red Sea it is evidently a Lessepsian migrant that reached the Mediterranean via the Suez Canal.

Keywords: *Bregmaceros nectabanus*, *B. atlanticus*, Mediterranean Sea, Introduced species, Suez Canal

Introduction

The Bregmacerotidae or codlets, are small elongated fishes with a maximum length of 12 cm. Members of this family are characterized by two dorsal fins, the first being a long single ray on the back of the head, and the second dorsal fin being long-based with rudimentary rays in the middle portion of the fin. The anal fin is very similar in form to the second dorsal and is situated directly below it. The family has been reviewed by D'Ancona & Cavinato (1965) and Belyanina (1974) and contains the single genus, *Bregmaceros* Thompson, 1840, containing 14 valid species (Eschmeyer, 2015). Codlets occur in tropical and subtropical neritic environments, with habitats ranging from mesopelagic to inshore and even estuaries. The state of our knowledge of the biology and geographic distribution of these fishes is not particularly good, even though they may be commonly encountered in midwater tows through much of their range. Even in the Mediterranean Sea, it

is not well known which species of *Bregmaceros* occur there. D'Ancona & Cavinato (1965) reported *B. atlanticus* Goode & Bean, 1886 from the Mediterranean based on a single questionable record, and to date that is the only species reported from the region (e.g., Turan *et al.*, 2011; Aydin & Akyol, 2013).

In this paper we conclude that the previous records of *B. atlanticus* from the Mediterranean Sea were misidentifications of *B. nectabanus* Whitley, 1941, the only member of this genus we confirm that occurs there. We provide a brief account here of *B. nectabanus*, including comparisons with material from the Indo-Pacific (the region including the type locality of *B. nectabanus*). We also provide a discussion of the occurrence of the species in the Mediterranean Sea possibly through dispersal from the Indo-Pacific via the Suez Canal and the Red Sea.

Materials and methods

Morphometric, meristic and other characters were determined following the methods and terminology of Hubbs & Lagler (1958), with modifications by D'Ancona & Cavinato (1965) and Torii *et al.* (2003a, b). Counts of

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rays for the second dorsal fin, anal fin, pectoral fin, and pelvic fin are the total number of rays. Number of rays in the caudal fin are reported as principal caudal fin rays or total caudal fin rays (including segmented and procurrent rays). Fin rays and counts of other serially repeating structures were determined from alcohol preserved specimens or from radiographic images.

Morphological characters and associated terms: D1, occipital first dorsal fin; D2, second (main) dorsal fin; A, anal fin; Pc, pectoral fin; Pv, pelvic fin; longitudinal scale count is the number of scales in a midlateral longitudinal series from the pectoral girdle to the posterior termination of the vertebral column (posterior margin of hypural plate); transverse scale count is the number of horizontal scale rows between the origins of the second dorsal fin and the anal fin; predorsal scale count is the number of lateral line scales along the dorsum (anterior, elevated portion of the lateral line) between the occiput and the origin of the second dorsal fin.

Morphometric characters were measured point to point with a Mitutoyo digital caliper. Names and descriptions of morphometric characters are as follows: Standard length (SL), distance (mm) from snout (most anterior location on premaxilla) to posterior termination of hypural plate; Preanal length, distance from snout to anal fin origin; Predorsal length, distance from snout to origin of second dorsal fin; Body depth, distance from second dorsal fin origin to anal fin origin; Head length (HL), maximum distance between snout and bony posterior margin of gill cover; Snout length, minimum distance between snout and anterior bony margin of orbit; Eye diameter, maximum horizontal distance across the eye; Interorbital width, minimum distance across cranium between orbits; Values of morphometric characters are reported as %SL, except those taken from within the

head (i.e., Snout length, Eye diameter, Interorbital width) which are %HL.

Results

Systematics

Infraclass TELEOSTEI Müller, 1845

Order GADIFORMES Goodrich, 1909

Family BREGMACEROTIDAE Gill, 1872

Genus *Bregmaceros* Thompson, 1840

Bregmaceros nectabanus Whitley, 1941

(Fig. 1, Table 1)

Bregmaceros nectabanus Whitley, 1941: 25, Figure 18 (type locality Darwin, Northern Territory, Australia [Arafura Sea, eastern Indian Ocean]). Munro, 1950: 41 (northwestern Australia); Shen, 1960: 68 (northern Australia); D'Ancona & Cavinato, 1965: 47 (Indian Ocean; central and western Pacific); Kotthaus, 1969: 39 (northwestern Indian Ocean; Red Sea); Belyanina, 1974: 11 [English translation] (Indian Ocean; western and central Pacific); Masuda & Ozawa, 1979 (type locality off Darwin, Northern Territory, Australia; Japan): 267; Dor, 1984: 58 (Red Sea); Okamura, 1984: 92 (Indian Ocean; western and southern Pacific); Masuda *et al.*, 1986: 393 (type locality off Darwin, northern Australia; Japan); Smith, 1986: 330 (Indo-West Pacific); Paxton & Hanley, 1989: 306 (northern Australia); Rivaton, 1989: 147–148 (New Caledonia); Cohen, 1990: 525 (Indian Ocean; tropical western Pacific to Fiji); Mamhot *et al.*, 1992: 50–53 (northern Australia; Japan); Goren & Dor, 1994: 15 (Red Sea); Iwamoto, 1999: 1997 (western central Pacific); Nakabo 2000: 415 (off Japan); Hutchins, 2001: 23 (off northwestern Australia); Nakabo, 2002: 415 (off Japan); Torii *et al.*, 2003a: 30 (northwestern Australia); Torii



Fig. 1 *Bregmaceros nectabanus*, HUJ 19928, 61 mm, trawled between Mikhmoret and Ga'ash off Israel

Table 1 Meristic and morphometric character values for *Bregmaceros nectabanus* from the Mediterranean Sea (HUJ 19751 and 19925) compared with Indo-Pacific material, including the holotype

Character	Holotype	Mediterranean Sea	Indian Ocean (Kotthaus, 1969)	Indian Ocean	Toyama Bay, Japan
No. specimens	1	10	8	18	138
SL (mm)	30.8	51.9–66.9	23.6–75.2	25.3–45.1	30.4–65.5
Total vertebrae	50	48–50	47–49	47–50	49–53
D2 fin rays	50	50–51	45–47	46–52	46–55
A fin rays	53	51–52	45–47	46–52	47–57
P fin rays	18	16–17	17–18	15–17	16–19
Principal caudal fin rays	13	13	-	13	13
Total caudal fin rays	29	27–30	-	27–29	27–32
Longitudinal scales	73 ^a	66–73	72–~80	71–74	71–80
Transverse scales	17 ^a	16–18	14–18	13–15	15–17
Head length %SL	18.5	16.5–18.9	16.2–20.0	17.0–19.1	15.8–18.8
Predorsal length %SL	39.0	38.9–41.8	39.1–46.1	39.4–41.9	37.6–43.0
Preanal length %SL	39.0	38.4–42.4	40.7–48.0	38.0–41.9	36.3–41.4
Body depth %SL	15.3	14.7–17.5	14.9–16.8	13.2–16.2	10.8–16.8
Snout length %HL	21.1	14.4–22.1	14.9–21.4	24.2–27.7	19.3–25.7
Eye diameter %HL	26.3	26.0–32.2	30.8–41.4	25.2–32.3	24.4–33.3
Interorbital width %HL	17.5	13.1–24.1	13.2–14.0 (26.8) ^b	18.7–24.5	14.7–21.3

Values for the holotype and specimens from off Japan based on Masuda *et al.* (1986), vertebral count for holotype confirmed from radiograph; values based on specimens from the Indian Ocean from original data (Discovery Sta. 54007, 54009, USNM 122665) or based on Kotthaus (1969)

^aFrom the original description (Whitley, 1941)

^bAnomalously high interorbital width for single large specimen (75.2 mm SL) recalculated here as %HL from Kotthaus (1969: 39, published values in %SL)

et al., 2003b: 138 (northern Australia; Japan); Paxton *et al.*, 2006: 622 (Indian Ocean; western Pacific); Shao *et al.*, 2008: 242 (South China Sea off Taiwan; northwestern Australia); Fricke *et al.*, 2011: 362 (New Caledonia); Shinohara *et al.*, 2011: 41 (Sea of Japan; northern Australia); Larson *et al.*, 2013: 52 (northern Australia); Shinohara *et al.*, 2014: 242 (Sea of Japan; northern Australia); Bogorodsky *et al.*, 2014: 414 (Red Sea; Indo-West Pacific).

? *Bregmaceros atlanticus* (non Goode & Bean, 1886). Yilmaz *et al.*, 2004: 111 (Antalya Bay, eastern Mediterranean Sea).

Bregmaceros atlanticus (non Goode & Bean, 1886). Goren & Galil, 2006: 1 (off Palmahim, eastern Mediterranean Sea); Filiz *et al.*, 2007: 108 (Aegean Sea); Turan *et al.*, 2011: 189 (eastern Mediterranean Sea); Aydin & Akyol, 2013: 245 (Izmir Bay, northern Aegean Sea).

Type material examined

Holotype: AMS IA.1719 (30.8 mm), Darwin, Northern Territory, Australia, 12°27'S 130°50'E, 1923, digital image and radiograph only.

Non-type material examined

BMNH unreg. (9, 29.9–38.9 mm SL), R/V Discovery Sta. 54009 #1, Indian Ocean. BMNH unreg. (8, 25.3–45.1 mm

SL), R/V Discovery Sta. 54009 #2, Indian Ocean. CAS 81511 (2, 25.8–52.3 mm), R/V Stranger Sta. 60–451, Gulf of Thailand, 13°21'45"N 100°32'43"E, 14 m, 14 Dec 1960. CAS uncat. (1, 34.0 mm), R/V Stranger Sta. 60–449, Gulf of Thailand, 12°19'15"N 100°43'40"E, 33 m, 13 Dec 1960. HUJ 19751 (6, 51.9–63.6 mm), off Israel. HUJ 19925 (4, 52.2–66.9 mm), off Israel. HUJ 19928 (1, 61.0 mm), trawled between Mikhmoret and Ga'ash off Israel.

Comparative material examined

Bregmaceros atlanticus Goode & Bean, 1886. Holotype, MCZ 32323 (44.1 mm), Caribbean Sea and Straits of Florida, USS Blake Exped., Stas. 045, 150 and 262 mixed, depth 90–500 fathoms (165–914 m), 1877. Non-types, *Bregmaceros atlanticus*, USNM 325140 (2, 66.0–71.3 mm), R/V Oregon Sta. 4417, off Venezuela, Caribbean Sea, 0–439 m, 04 Oct 1963.

Diagnosis

A species of *Bregmaceros* with 47–55 dorsal and 47–57 anal fin rays, 15–19 pectoral fin rays, 13 principal caudal fin rays, 69–80 longitudinal scales, 15–17 transverse scales, unpigmented (or nearly so) abdomen, and a distinctive thin brown dorsolateral longitudinal stripe below the second dorsal fin. Opercular spine distally fimbriate.

Species comparisons

Bregmaceros contains 14 valid nominal species (Eschmeyer, 2015) and at least four undescribed species (Harold, unpublished). Of the valid nominal species, *B. nectabanus* is distinguished from *B. atlanticus*, *B. cayorum* Nichols, 1952, *B. houdei* Saksena & Richards, 1986, *B. japonicus* Tanaka, 1908, *B. neonectabanus* Masuda *et al.*, 1986, *B. bathymaster* Jordan & Bollman, 1890, *B. rarisquamosus* Munro, 1950, and *B. cantori* Milliken & Houde, 1984, based on the presence of a distally fimbriate opercular spine in *B. nectabanus*, compared with a spine with a distally unornamented point in the other species (see Torii *et al.*, 2003a, b). Species that share the presence of a fimbriate opercular spine with *B. nectabanus* are *B. arabicus* D'Ancona & Cavinato, 1965, *B. pescadorus* Shen, 1960, *B. mccllellandi* Thompson, 1840, *B. lanceolatus* Shen, 1960, and *B. pseudolanceolatus* Torii *et al.*, 2004. Of these species, *B. nectabanus*, *B. arabicus*, *B. pescadorus*, and *B. mccllellandi* all have an indented caudal fin posterior margin as compared with the two species, *B. lanceolatus* and *B. pseudolanceolatus*, with a lanceolate caudal fin. *Bregmaceros nectabanus* has a distinctive thin brown dorsolateral longitudinal stripe below the second dorsal fin, as compared with multiple longitudinal rows of minute spots in *B. arabicus* and *B. pescadorus*, or a darkly pigmented dorsum but lacking any longitudinal pigment stripes or rows of dots in *B. mccllellandi*. With respect to overall similarity, *B. nectabanus* is closest to *B. neonectabanus*, but the former differs in its lack of pigmentation on the abdomen (compared with the presence of dark pigment in that area), and the presence of 13 principal caudal fin rays in *B. nectabanus*, as compared with 14.

The only species of *Bregmaceros* to have been reported from the Mediterranean Sea to date is *B. atlanticus* (D'Ancona & Cavinato, 1965, and others cited above). Based on the original description and our examination of the type and other non-type specimens from the Atlantic ocean, *B. atlanticus* is very darkly pigmented over almost the entire body, has a relatively elongate body (body depth 12.4–14.4 % SL), and a simple opercular spine termination. On the other hand, *B. nectabanus* has the distinctive body pigmentation pattern including a thin dorsolateral stripe, a typically greater body depth (13.2–17.5 % SL in the *B. nectabanus* material reported herein from the Mediterranean, the Indian Ocean, and the type locality) and a fimbriate opercular spine termination. The minimum value of body depth for *B. nectabanus* from off Japan was reported by Masuda *et al.* (1986) to be 10.8 % SL (Table 1), a rather low value for the species, but we are unable to verify it.

The status of *Bregmaceros nectabanus* and associated type material was considered in detail by Masuda *et al.* (1986). The species had previously been known to have

a broader distribution, including the southeastern Atlantic, the Indian and the western Pacific regions. Masuda *et al.* (1986) restricted the use of *B. nectabanus* and designated a new species, *B. neonectabanus*, based on a number of meristic and pigmentation characters. The summary of the distribution of *B. nectabanus* provided by Eschmeyer (2015) includes the Red Sea, the Indo-West Pacific region and the Atlantic, although Masuda *et al.* (1986: 392) excluded the Atlantic material and reassigned it to *B. neonectabanus*. Occurrences of *B. nectabanus* in the western Indian Ocean and the Red Sea are few (Kotthaus, 1969; Dor, 1984) but we have been able to verify the identity of material from the area. Other relevant material from the Red Sea reported by Bogorodsky *et al.* (2014) is similar to *B. nectabanus*, but may not be conspecific.

Discussion

The first record of a member of the Bregmacerotidae from the Mediterranean was reported by D'Ancona & Cavinato (1965) off the coast of southern Italy, based on a questionable identification of a specimen identified as *Bregmaceros atlanticus*. It is not clear at all from the account of the species provided by D'Ancona & Cavinato (1965) what the source of the record was and, furthermore, they may not have examined the specimen. However, others have followed, indicating the questionable status of that record (Cohen, 1986; Goren & Galil, 2006). These authors were also unable to examine the specimen, nor is the specimen explicitly referred to or listed as material examined in D'Ancona & Cavinato (1965). Since the source of this initial record of *B. atlanticus* from the Mediterranean is unknown, and neither specimens nor descriptive data are known, we treat it as *Bregmaceros* sp. only. We also find that their account of *B. atlanticus* takes a rather broad view of variation in the species and may include representatives of at least one other undescribed species. It has been shown that D'Ancona & Cavinato (1965) often employed a rather expansive interpretation of intraspecific variation (Torii *et al.*, 2003b). The first record of *B. atlanticus* from the Mediterranean for which specimens and data were reported was Yilmaz *et al.* (2004), who reported two specimens from the stomach contents of the Lessepsian (Red Sea) migrant, the Brushtooth Lizardfish *Saurida undosquamis*, in Antalya Bay, Turkey. Although the counts of fin rays for the second dorsal and anal fins fall within the range of *B. atlanticus*, the pattern of pigmentation is not consistent with published descriptions ("silver-grey on the belly with dense pigmentation along the dorsum"), as compared with darkly pigmented over the entire body and fins (D'Ancona & Cavinato, 1965; Belyanina, 1974). About 2 years later, Goren & Galil (2006) reported four specimens of *B. atlanticus* from a

trawl catch from a depth of about 35 m off the coast of Israel. The records of Filiz *et al.* (2007) extended the range of *B. atlanticus* in the Mediterranean to the eastern Aegean Sea, and later to the northern region of that sea (Aydin & Akyol, 2013). Turan *et al.* (2011) reported the species from a depth of 120 m in Iskenderun Bay at the northeastern corner of the Mediterranean. However, based on the specimen data and photographs published in the foregoing accounts these records represent occurrences of *B. nectabanus* in the Mediterranean, not *B. atlanticus*. Apparently, *B. nectabanus* has established a sustainable population along the Israeli coast with dozens of specimens being collected, mainly between depths of 30 and 50 m, and why it was not collected in the eastern Mediterranean prior to D'Ancona & Cavinato's (1965) report is unknown. It is possible it invaded the area or increased in population size significantly since the time of their report.

Regarding its distribution in the Atlantic, according to the revision of Masuda *et al.* (1986), *B. nectabanus* is not known to occur there, thus excluding it as a possible source of individuals dispersing into the Mediterranean Sea. We report here the first occurrence of *B. nectabanus* from the Mediterranean Sea. Previous reports of *B. atlanticus* from the Mediterranean cannot be substantiated and the former may be the only species of the genus, and indeed the family Bregmacerotidae, to occur there.

Three species of *Bregmaceros* have been mentioned in the literature as possibly occurring in the Red Sea: *B. nectabanus*, *B. arabicus*, according to Aron & Goodyear (1969), and *B. mccllellandi*, however, according to D'Ancona & Cavinato (1965) the latter's occurrence there was most likely a result of misidentification of *B. arabicus* (see Dor, 1984). *Bregmaceros mccllellandi*, in the restricted sense of Torii *et al.* (2003b), and as supported by observations of the first author, has not been recorded from the western Indian Ocean or the Red Sea. As for *B. nectabanus*, this species was reported by Kotthaus (1969) and Bogorodsky *et al.* (2014) from the Red Sea and by Belyanina (1974) from the Gulf of Oman at the southern entrance of the Red Sea. Our material from the Mediterranean is clearly conspecific with *B. nectabanus*, with little variation from specimens reported from across the range of the species (Table 1; Kotthaus, 1969; Masuda *et al.* 1986).

Goren & Galil (2006) wondered as to the source of *Bregmaceros* species in the Mediterranean. Given that numerous fish collections in the region over many years did not reveal *Bregmaceros* species, it seems likely that the population became established there following dispersal from elsewhere. The opening of the Suez Canal in 1869 resulted in the influx of over 600 species from the Red Sea into the Mediterranean (Galil, 2009; Zenetos,

2010), among these were 97 migrant fish species (Fricke *et al.*, in press). Such species have been referred to as Lessepsian migrants (see Golani, 2010). Goren & Galil (2006) raised the possibility that *Bregmaceros* species entered the Mediterranean in ballast water or through dispersal via the Suez Canal. The present findings and the inferred rapid population growth, which is typical of Lessepsian migrant fish species (Golani, 2010), indicate that *B. nectabanus* most likely entered from the Red Sea via the Suez Canal. Kotthaus (1969) reported this species from the extreme southern end of the Red Sea as well as the Gulf of Oman and the Arabian Sea; additional records tentatively referred to this species from the Red Sea have been reported (Bogorodsky *et al.*, 2014). There are no substantiated records of *B. nectabanus* from the Atlantic, thus excluding it as a possible source. *Bregmaceros nectabanus* had been recorded from the South Atlantic (D'Ancona & Cavinato, 1965) and it is widely reported to occur there but Masuda *et al.* (1986) reassigned those records to *B. neonectabanus*.

Conclusions

We have reviewed published records of *Bregmaceros atlanticus* from the Mediterranean Sea and examined type and non-type specimens of this and other species belonging to this genus. Morphometric and meristic data, in addition to qualitative observations were used as the basis of interspecific comparisons. We have determined that all previously published records of *B. atlanticus* from the Mediterranean Sea, the first being D'Ancona and Cavinato (1965), are based on misidentifications, and that *B. nectabanus* is the correct identity of all such verifiable records. Therefore, this is the first record of *B. nectabanus* from the Mediterranean and it is the only species of *Bregmaceros* known to occur in the region. *Bregmaceros nectabanus* was originally described from off Australia and is known to have a natural range including much of the Indo-Pacific region but not the Atlantic. We conclude that the species now occurs in the Mediterranean Sea as a result of dispersal from the Red Sea via the Suez Canal (Lessepsian migrant).

Abbreviations

Material examined is listed by institutional acronym and catalog number or vessel and collecting station number; number of specimens examined and the size range in standard length of those specimens from which data were taken; institutional abbreviations are as follows:

AMS, (Australian Museum, Sydney); BMNH, (The Natural History Museum, London); CAS, (California Academy of Sciences); HUJ, (Hebrew University of Jerusalem); KAUMM, (King Abdulaziz University Marine Museum, Jeddah, Saudi Arabia); MCZ, (Museum of Comparative Zoology, Harvard University); SMF, (Senckenberg Forschungsinstitut und Naturmuseum); USNM, (National Museum of Natural History, Smithsonian Institution) (abbreviations as listed in Sabaj Perez, 2014).

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Availability of data and materials

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Authors' contributions

The authors contributed approximately equally to all aspects of this paper. Both authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

Ethics approval and consent to participate

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