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Rapid Communication

First record of the Goldstripe sardinella - *Sardinella gibbosa* (Bleeker, 1849) in the Mediterranean Sea and confirmation for its presence in the Red Sea

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Abstract

This report updates the geographical distribution of *Sardinella gibbosa* (Bleeker, 1849): confirming its presence in the Red Sea and documenting its introduction into the Eastern Mediterranean Sea. Both updates are based on overlooked museum voucher specimens, some of which were collected 86 years ago. In addition, a simplified morphological key is provided for identifying the clupeids currently found in the Eastern Mediterranean Basin.

Key words: alien species, Clupeidae, Levant Basin, Mediterranean, Red Sea, Lessepsian migration

Introduction

The goldstripe sardinella *Sardinella gibbosa* (Bleeker, 1849) is a commercially important marine sardine (Clupeidae) with average annual landings of 227,000 t during 2008–2012 (FAO yearbook 2012). It is a coastal pelagic species that inhabits the Indo West-Pacific region from north Australia in the east to the western borders of the Indian Ocean including the Persian Gulf (Whitehead 1985) and the Red Sea (Dor 1984). However, due to several questionable identifications, the Red Sea was later omitted from its geographic distribution (Whitehead 1985; Golani and Bogorodsky 2010).

In this study, we confirm the existence of *S. gibbosa* in the Red Sea, based on the examination of type specimens archived at the Muséum National d'Histoire Naturelle, Paris, France (MNHN) and specimens from the fish collection of the Hebrew University of Jerusalem, Israel (HUJ).

In addition, we have discovered the occurrence of *S. gibbosa* from the Israeli Mediterranean coast from specimens collected during bottom trawl surveys conducted in 2011–2012. Re-examination of the clupeid collection at the Steinhardt Natural History Museum and National Research Centre at Tel Aviv University, Israel (TAU) revealed 60 specimens of *S. gibbosa* previously collected from the Eastern Mediterranean Sea with the earliest specimen during April 2008 (voucher specimen TAU P.13954). All of these specimens had been erroneously identified and vouchered as the Mediterranean indigenous species *Sardinella maderensis* (Lowe, 1839).

The opening of the Suez Canal in 1869 enabled a remarkable and continuing influx of biota from the Red Sea into the Mediterranean, including more than ninety Indo-Pacific fishes (Golani and Appelbaum-Golani 2011; Galil and Goren 2013; Stern and Goren 2013). Among this alien fauna, four invasive clupeids have already established proliferating populations: *Herklotsichtys punctatus* (Rüppell, 1837), reported in Bertin (1943); *Dussumieria elopsoides* Bleeker, 1849, in Ben-Tuvia (1953); *Etrumeus golanii* DiBattista, Randall and Bowen, 2012, documented as *Etrumeus teres* (DeKay, 1842) in Whitehead (1963) and *Spratelloides delicatulus* (Bennet, 1831) in Ben-Tuvia (1978). *E. golanii*, originally documented as *E. teres*, was the first to reach the Strait of Sicily, central Mediterranean (Falautano et al.

2006). The remaining three species are still confined to the Eastern Mediterranean.

This report elevates the number of non-indigenous clupeid at the Mediterranean to five and the total number of clupeids in the Eastern Mediterranean to nine. In order to minimize future taxonomic difficulties, an updated morphological key to the clupeids of the Eastern Mediterranean is provided.

Material and methods

Morphological characters were measured using digital calipers with 0.01 mm accuracy. Length of specimens is given as standard length (L_S), instead of total length, due to the occasional disfigurement at the tip of the caudal fin. Body height was measured at the dorsal fin origin. Pre-dorsal, pre-pelvic, and pre-anal lengths were measured from the tip of the snout to the origin of the corresponding fin. Scales from the anterior, middle, and posterior parts of the body were sampled and examined under a light stereoscope. The first gill arch was gently removed from the left side of each specimen and examined under a light stereoscope. The morphological key was based on the catalogued species of Whitehead (1985) and from the fish collection at TAU.

Results

Sardinella gibbosa (Bleeker, 1849)

(Figure 1; Table 1)

Clupea gibbosa (Bleeker, 1849). J. Ind. Arch. 3:72. (Makassar, Indonesia).

Clupea immaculata Kishinouye 1907. J. Imp. Fish. Bur. Tokyo, 14: 3 96, pls. 19, figure 1, 21, 4 (Saga, Kyushu, Japan. Arnoy, Swatow, China) [syn. by Whitehead (1985)].

Harengula dollfusi Chabanaud 1933. Bull. Inst. Ocean. Monaco. 627: 1–12. (Gulf of Suez, Red Sea) [syn. by Dor (1984)].

Fimbriclupea dactylolepis Whitley, 1940. Aust. Zoo. 9(4):399. Figure 5. (NW Australia) [syn. by Whitehead (1985)].

Sardinella taiwanensis Raja & Hiyama, 1969, Rec. Ocean. Jap, 10:1, 90, pl. 2b (Taiwan) [syn. by Whitehead (1985)].

Material examined

Red Sea specimens (17 individuals): **MNHN** 1942-0047/48 (4 spec. 127–150 mm), Gulf of Suez, Egypt, 1928; MNHN 1966-0343/4 (paratypes of *Harengula dollfusi* Chabanaud, 1933, 2 spec. 89, 100.2 mm), Gulf of Suez, Egypt, 16 Jan 1929; **MNHN** 1966-0261 (one of the paratypes of *Dussumieria productissima* Chabanaud, 1933, 1 spec. 103 mm), Gulf of Suez, Egypt, 16 Jan 1929; **HUJ** 14336 (1 spec. 102.2 mm), Shab Shiaks, Eritrea, 10 Dec 1957; **HUJ** 14314 (1 spec. 94.4 mm), Eritrea, 31 Dec 1957; **HUJ** 6286 (2 spec. 108.4, 113 mm), Gulf of Suez, Egypt, 11 Nov 1972; **HUJ** 12895 (2 spec. 111.8, 130 mm), Gulf of Suez, Egypt, 11 Nov 1972; **HUJ** 9084 (4 spec. 93.1–132.8 mm), Gulf of Suez, Egypt, 23 May 1973.

Mediterranean specimens (48 individuals): **TAU** P.13954 (3 spec. 115–120 mm), Ashdod, Israel, 06 Apr 2008; **TAU** P.13617 (1 spec. 122.5 mm), Ashdod, Israel, 20 Apr 2008; **TAU** P.13982 (13 spec. 115–125 mm), Palmachim, Israel, 07 Jul 2009; **TAU** P.14326 (17 spec. 114–131 mm), Ashdod, Israel, 11 May 2011. TAU P. 14492 (3 spec. 106–117 mm), Ashdod, Israel, 30 Jan 2012; **TAU** P.15092 (2 spec. 75.5, 79.8 mm), Ashdod, Israel, 07 Aug 2012; **TAU** P.14833 (1 spec. 103.8 mm), Nizzanim, Israel, 21 Oct 2012; **TAU** P.15090 (8 spec. 73.85.4 mm), Nizzanim, Israel, 26 Nov 2012.

Comparative material

Sardinella albella (Valenciennes, 1847) (31 individuals): type material - **MNHN** 0000-3231 (1 spec. 74.5 mm), Pondicherry, India, 1818; **MNHM** 0000-0665 (1 spec. 72.2 mm), Pondicherry, India, 1825. Other material - **TAU** P.15203 (25 spec. 63.9-88 mm), Vanga, Kenya, 07 Apr 2013; **TAU** P.15208 (2 spec. 86.6, 95.3 mm), Jasini, Kenya, 07 Apr 2013; **TAU** P.15209 (2 spec. 72.3, 79.3 mm), Vanga, Kenya, 07 Apr 2013.

Sardinella aurita (11 individuals): type material – **MNHN** A-9824 (1 spec. 170 mm), Sicily, Italy, 1829. Other material – TAU P.14325 (10 spec. 127–160 mm), Ashdod, Israel, 11 May 2011.

Sardinella fimbriata (Valenciennes, 1847) (31 individuals): type material - **MNHN** 0000-3227 (1 spec. 123.3 mm), Malabar Coast, India, 1837; **MNHN** B-3084 (3 spec. 122.7–127.2 mm), Malabar Coast , India , 1837 . Other material – **TAU** P. 15438 (27 spec. 60.7–127.1 mm), Manila district, Philippines, 08 June 2014.

Sardinella maderensis (5 individuals): type material – **MNH**N 0000-0003 (1 spec. 225 mm), Gorée, Senegal, 1830. Other material – **TAU** P.15439 (4 spec. 119–172 mm), Akko, Israel, 07 April 2014.

Figure 1. *Sardinella gibbosa*, TAU P.15090, 122.5 mm L_S, Ashdod, Israel Mediterranean, 26 Nov 2012 (Photo: O. Rittner).

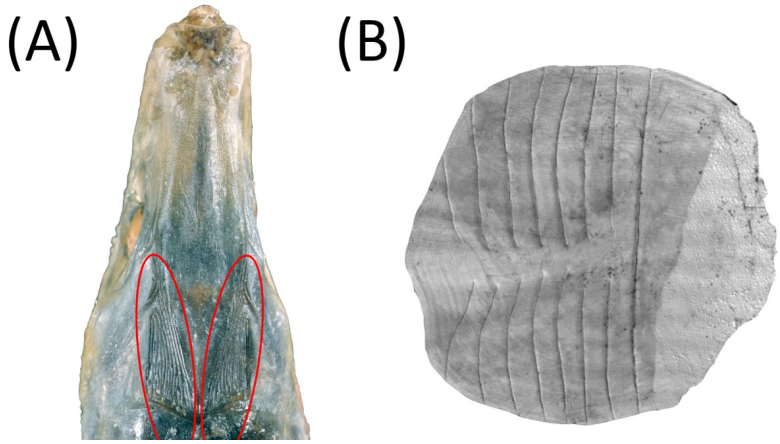

Figure 2. (A) Fronto-parietal striae on top of *S. gibbosa*'s head, dorsal view, encircled; (B) Lateral scale of *S. gibbosa*, TAU P.15090.

Diagnosis

Sardinella gibbosa is morphologically distinguished from its congeneric by the combination of four characters: (1) slender body, its height ranges 21.4–28.2% of its L_S; (2) 33 ventral scutes; (3) 46–61 gill rakers on the lower arm of the first arch, increasing with size of fish; and (4) interrupted longitudinal striae formation in lateral scales (Figure 2B). Differentiating *S. gibbosa* from the Mediterranean con-sub-generic *S. maderensis* is mainly based on the significant gap in lower gill rakers counts; 77–166 in *S. maderensis vs*. 46–61 in *S. gibbosa* and in the deeper bifurcated caudal fin of *S. maderensis* where the length of the forked caudal fin lobes constitutes an average of 70.5% of total tail length *vs*. 53.13% in *S. gibbosa*.

Brief description

Based on selected meristic and morphometric measurements (Table I): slender species of *Sardinella* with elongated and compressed body shape. Mouth terminal with minute teeth on lower jaw and tongue. Two triangular formations are present on top of head, each composing 9–13 fronto-parietal striae (Figure 2A). Dorsal fin rays average count 18; pectoral fin with 14–16 rays, tightly embedded in a triangular groove. Pelvic fin with eight rays; triangular axillary scale above the origin of the pelvic fin is equal in length to the longest pelvic ray. Anal fin with 18–20 rays, averaging 19.3; last two anal rays enlarged, thickened and branched. Lateral scales deciduous; scales with one continuous vertical striae followed by 5–9 discontinuous striae,

Table 1. Meristic and morphometric characters for *Sardinella gibbosa* from the Res Sea and the Eastern Mediterranean. SD – standard deviation.

	range	Mean	SD
Meristics			
Standard length (LS in mm)	73.8-150	108.2	26.3
Dorsal rays	16-19	17.9	1.08
Anal rays	18-20	19.3	0.66
Pectoral rays	14-16	14.7	0.8
Ventral scutes	32-33	32.5	0.47
Upper limb gill rakers count	24-34	28.2	2.8
Lower limb gill rakers count	46-67	58	4.8
Morphometrics - % of L_S			
Body height	21.4-28.2	24.8	1.7
Predorsal fin length	40.4-45	42.6	1.06
Prepelvic fin length	46.1-51	48.9	1.08
Preanal fin length	72.3-78.4	75.2	1.48
Head length	21.2-24.3	22.5	0.83

interrupted in the centre; exposed part of scales slightly eroded and perforated (Figure 2B). Prepelvic and post-pelvic ventral scutes count 18+14, respectively, 32 in total. Gill rakers on lower arm of the first gill arch count less than 50 in juveniles under 100 mm L_S, gradually increasing up to 61 at the size of 150 mm L_S. Adult specimens present a distinct golden blotch (darkens after preservation) at the margins of the operculum, approximately the size of the pupil. Dark spot also present at the base of the dorsal fin, tinting the membrane of the anterior four dorsal rays. Faint shades are present at the tip of the snout and at the tips of the dorsal and caudal fins. A pale thin horizontal golden line along the flank can be occasionally observed in fresh specimens.

Remarks

The present research at MNHN has revealed that the two paratypes of *Harnegula dollfusi* (Chabanaud, 1933), MNHN 1966-0343 and 1966-0344, that were previously identified by Whitehead (1985) as a *S. albella* were in fact *S. gibbosa*, in accordance with Dor (1984). In addition, one of the paratypes of *Dussumieria productissima* (Chabanaud, 1933), MNHN 1966-0261, previously identified by Whitehead (1985) as *S. fimbriata* was also found as *S. gibbosa*. *D. productissima* was synonymized with *D. elopsoides* by Whitehead and Bauchot (1985); this particular specimen was likely erroneously vouchered by Chabanaud and was later misidentified by Whitehead. The similar morphological appearances of *S. albella*, *S. gibbosa,* and *S. fimbriata* as well as the insufficient taxonomic knowledge often led to misidentifications in natural history fish collections (unpublished data). Reliable identification of these specimens can be achieved based on (1) the number of ventral scutes – 32 in *S. gibbosa versus* 30–31 in *S. albella* and *S. fimbriata*; (2) the number of anal fin rays – 18–19 in *S. gibbosa versus* 20–23 in *S. albella* and *S. fimbriata* and (3) body height - less than 28% of its L_S in *S. gibbosa* vs. higher body with 29–35% of its L_S for *S. albella* and *S. fimbriata*.

Key to the clupeids of the Eastern Mediterranean Sea

(Introduced Indo-Pacific species are designated with an asterisk).

1a. Upper jaw with a median triangular notch (Subfamily Alosinae) …… *Alosa fallax* (Lacepède, 1803)

1b. Upper jaw with a median rounded notch …… 2

2a. Belly keeled with sharp scutes (Subfamily Clupeinae) ……..…… 3

2b. Belly rounded with one W-shaped pelvic scute (Subfamily Dussumieriinae) ……..…… 7

3a. Pelvic fin with nine rays ……..…… ……..…….. *Sardinella aurita* Valenciennes, 1847

3b. Pelvic fin with eight rays ……..…….. 4

4a. Distinct radiating bony striae on lower part of operculum …….. *Sardina pilchardus* (Walbaum, 1792)

4b. Lower part of operculum without radiating bony striae ……..…… 5

5a. Dark spot at dorsal fin origin; no black spot along midline of the back ……..…….. 6

5b. No dark spot at dorsal fin origin; black spots along midline of the back …… ……..…. *Herklotsichthys punctatus** (Rüppel, 1837)

6a. Deeply forked caudal fin, fork length constitutes approx. 70% of total caudal fin length; more than 70 gill rakers in lower gill arm of first arch in specimens over 60 mm L_S …… ……..…. *Sardinella maderensis* (Lowe, 1838)

6b. Moderately forked caudal fin – fork length constitutes approx. 53% of total caudal fin length; 46–67 gill rakers in lower gill arm of first arch in specimens of 70–150 mm L_S …… …… *Sardinella gibbosa** (Bleeker, 1849)

7a. Numerous branchiostegal rays (11 to 17) ….. 8

7b. 6 to 7 branchiostegal rays …… …….. *Spratelloides delicatulus** (Bennett, 1832)

8a. Pelvic fin under dorsal fin base …… …….. *Dussumieria elopsoides** Bleeker, 1849

8b. Pelvic fin origin posterior to dorsal fin base … *Etrumeus golanii** DiBattista, Randall and Bowen, 2012

Discussion

Due to the relatively clear taxonomy of fishes, reports on non-indigenous species are often well verified and accurate (Golani and Appelbaum-Golani 2011). Nevertheless, an occasional lack of adequate preserved material or difficult taxonomy may lead to incorrect documentation or unnoticed introductions, such as suggested by Fricke et al. (2012).

High similarities between *S. maderensis* and *S. gibbosa* in many external morphological characters have hindered the recognition of the latter as a non-indigenous species in the Eastern Mediterranean. The prominent character of eight pelvic fin rays *vs*. nine in *S. aurita*, has positioned *S. maderensis* as the only clupeid belonging to the subgenus *Clupeonia* in the Mediterranean, prior to the present report of *S. gibbosa*.

Reconfirming the occurrences of *S. gibbosa* at the Red Sea in general, and in the Gulf of Suez in particular, explains its recent introduction to the Mediterranean since the Suez Canal functions routinely as the predominant gateway for alien biota to the Mediterranean (Coll et al. 2010). This study emphasized the need for careful taxonomic examinations to avoid species' misidentifications, which hinders efforts to describe biodiversity or to detect biological invasions.

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