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Sagum posteli Delamare-Deboutteville & Nunes-Ruivo, 1954 (Copepoda: Siphonostomatoida: Lernanthropidae) parasitic on *Epinephelus aeneus* (Geoffroy Saint-Hilaire) in Turkish waters, with a key to the species of *Sagum* Wilson, 1913

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Abstract *Sagum posteli* Delamare-Deboutteville & Nunes-Ruivo, 1954 (Copepoda: Lernanthropidae) is reported from the white grouper *Epinephelus aeneus* Geoffroy Saint-Hilaire caught off the Turkish Mediterranean coast. This documents the first discovery of this species in the Mediterranean and is only the second record. The species is redescribed from adult females and the cephalothoracic limbs are described for the first time. The valid species of the genus *Sagum* Wilson, 1913 are reviewed, and the poorly described species *S. poeyi* Ortiz, Lalana & Suarez, 2003 is relegated as a junior synonym of *S. texanum* Pearse, 1952, described from the same host. A key is provided to females of the ten valid species of *Sagum* and the known hosts for all species are summarised.

Introduction

According to the phylogenetic revision of Ho & Do (1985), there are eight valid genera in the Lernanthropidae Kabata, 1979, a family of parasitic copepods found exclusively on marine teleost fishes. In their comprehensive analysis of copepod parasites reported from Mediterranean fishes, Raibaut et al. (1998) listed only the type-genus, *Lernanthropus* de Blainville, 1822, as present and recognised nine species as occurring on marine fish hosts in the Mediterranean. These species were all listed as members of *Lernanthropus* by Raibaut et al. (1998): *L. gisleri* van Beneden, 1852, *L. trachuri* Brian, 1903, *L. kroyeri* van Beneden, 1851, *L. vorax* Richiardi, 1879, *L. mugilis* Brian, 1898, *L. foliaceus* Richiardi, 1878, *L. micropterygis* Richiardi, 1885, *L. scribae* Krøyer, 1863, and *L. tylosuri* Richiardi, 1880. Some of these species are now placed in different genera. Ho & Do (1985) transferred *Lernanthropus trachuri* to *Lernanthropinus* Do in Ho & Do, 1985 as *L. trachuri* (Brian, 1903). Hewitt (1968) based his new genus *Paralernanthropus* Hewitt, 1968 upon *Lernanthropus foliaceus* as the type-species but attributed it to Goggio (1905), since the use of the name by Richiardi (1878, 1880) constituted a *nomen nudum*. Ho & Do (1985) synonymised *Paralernanthropus* with *Sagum* Wilson, 1913, and so the current valid binomen for this taxon is *S. foliaceus* (Goggio, 1905). A fourth genus of lernanthropid, *Mitrapus* Song & Shen, 1976, was recently reported from the Mediterranean on invasive fish hosts of Red Sea origin (El-Rashidy & Boxshall, 2009, 2010).

Until now, only three species of lernanthropids have been reported from Turkish waters: *Lernanthropinus trachuri* (Brian, 1903), *Lernanthropus brevis* Richiardi, 1879 (Akmirza, 2003) and *L. kroyeri* van

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Beneden, 1851 (Toksen, 1999; Öktener & Trilles, 2004; Korun & Tepecik, 2005; Toksen, 2007). In this article, we report on the discovery of a second representative of *Sagum* from the Mediterranean, and the first from Turkish waters.

Materials and methods

Local caught fish were purchased at the fish market in Izmir, Turkey. Parasites were collected from the gill filaments of the host, fixed in 10% formalin and brought to the laboratory for detailed investigation. The copepods were dissected, mounted in lactophenol as temporary slide preparations and examined under an Olympus compound microscope equipped with Differential Interference Contrast optics. Measurements were made using an ocular micrometer, and drawings were made with the aid of a drawing tube.

Material for scanning electron microscopy (SEM) was fixed in 2.5% glutaraldehyde in 0.1 M phosphate buffer (pH 7.4) at 4°C (overnight), and then washed twice in buffer and once in distilled water, dehydrated through a graded ethanol series and air dried. Specimens were mounted on aluminium stubs and sputter coated with gold. SEM photographs were taken using a JEOL JSM-5200 (Tokyo, Japan) scanning electron microscope.

Morphological terminology follows Boxshall (1990) and Huys & Boxshall (1991). Host names were validated against FishBase (Froese & Pauly, 2011).

Family Lernanthropidae Kabata, 1979
Genus *Sagum* Wilson, 1913

Sagum posteli Delamare-Deboutteville & Nunes-Ruivo, 1954

Host: Epinephelus aeneus (Geoffroy Saint-Hilaire).
Locality: Eastern Mediterranean waters off Izmir, Turkey.
Site on host: Gills.
Material: Two partly dissected females stored in IMS (industrial methylated spirit) in the collections of the Natural History Museum, London, Registration no. BMNH 2011.8652-8653. Two additional females are stored in collection of the first author.

Description (Figs. 1–4)

Female

Body comprising cephalothorax and trunk (Fig. 1A-C); body length of two intact specimens 7.00 and 7.39 mm. Cephalothorax *c*.1.6–1.7 times wider than long; lateral margins expanded laterally into ventrally directed folds on both sides of cephalothorax (Fig. 1A,B). Frontal margin of cephalothorax produced into medial lobe, and antero-lateral corners produced into smaller lobes, giving frontal margin crenulate appearance. Trunk comprising anterior part bearing well-defined rectangular tergite of second pedigerous somite, and produced into tapering posterolateral processes on each side. Posterior part of trunk covered by expansive dorsal plate, covering entire abdomen and caudal rami, but with tips of fourth legs visible in dorsal view in some specimens; dorsal plate with rounded posterolateral margin (Fig. 1A). Urosome comprising genital complex and abdomen with paired, digitiform caudal rami (Fig. 1D). Genital complex with vestiges of fifth legs located on ventral surface anterior to paired genital openings. Caudal rami tapering to weakly cuticularised tip, apparently lacking any setation (Fig. 1D). Loosely coiled uniseriate egg strings located in space between dorsal plate of trunk and lamellate legs 3 and 4.

Antennule (Fig. 2B) indistinctly seven-segmented; proximal three segments separated only by slight furrows; middle three segments separated by vestiges of articulations marked by thinner cuticle; apical segment with well-defined proximal articulation; setal formula 0: 2: 0: 1: 0: 0: 9. Lacking parabasal flagellum.

Antennae (Figs 2A, 4A) robust and located on heavily sclerotised common pedestal; each antenna comprising massive corpus bearing small papilliform element located in depression on postero-medial surface (Fig. 4B) and distal subchela. Subchela strongly curved, showing traces of suture line proximally on concave margin (Fig. 3A).

Mandible stylet-like, armed with seven marginal teeth distally (Fig. 1E). Mandibles located within oral cone formed from anterior labrum and posterior labium; labium larger than labrum and forming lateral and posterior parts of oral opening, these parts being ornamented with fine surface spinules (Fig. 4C); labrum unornamented. Maxillule (Fig. 2C) bilobate; smaller outer lobe tipped with single spiniform element; larger inner lobe tipped with three unequal spiniform elements.

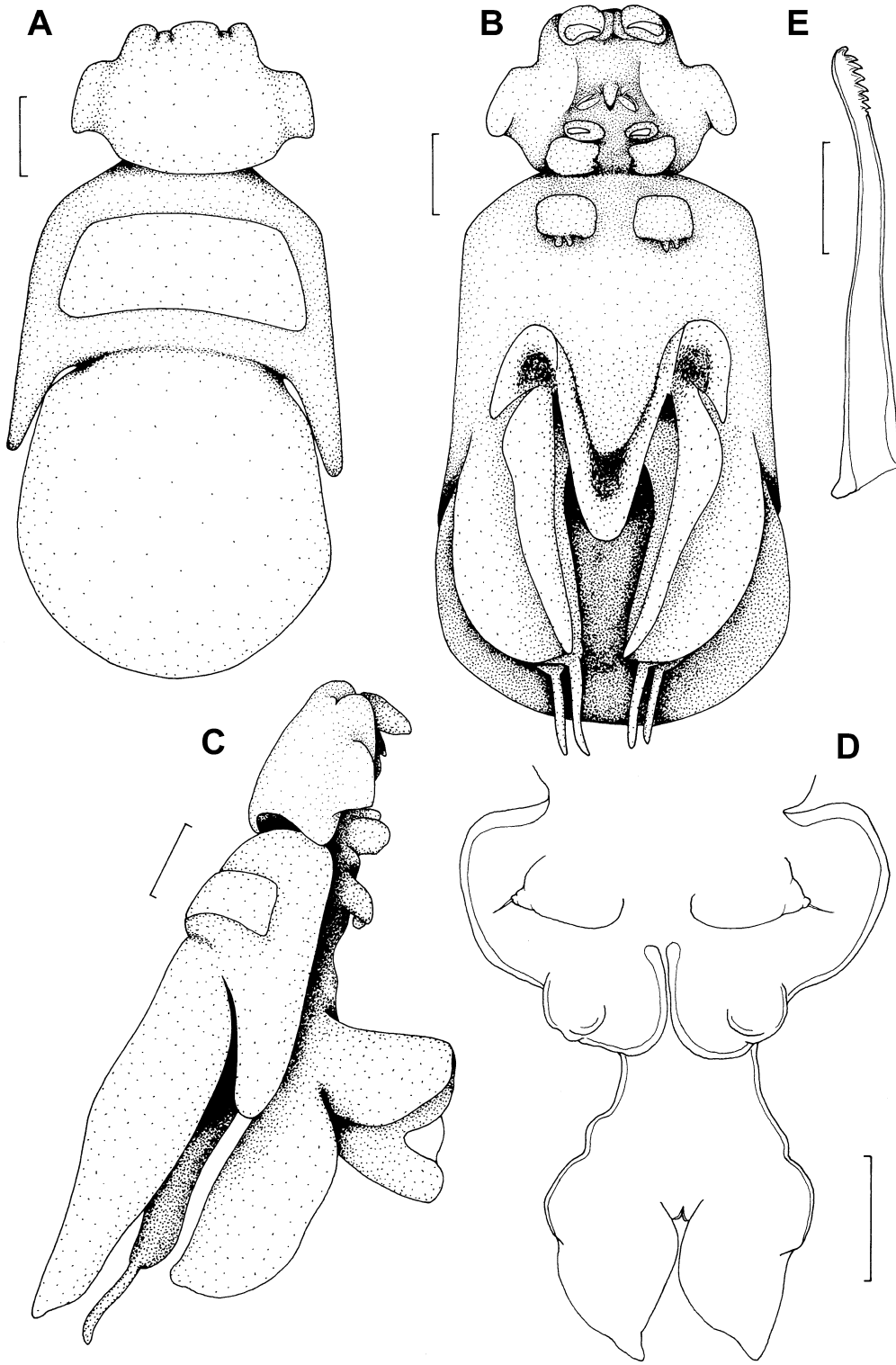

Fig. 1 *Sagum posteli* Delamare-Deboutteville & Nunes-Ruivo, 1954, female. A, habitus, dorsal view; B, habitus, ventral view, with egg strings removed; C, habitus, lateral view; D, genitoabdomen and caudal rami, ventral view; E, mandible. *Scale-bars*: A–C, 1.0 mm; D, 100 μm; E, 25 μm

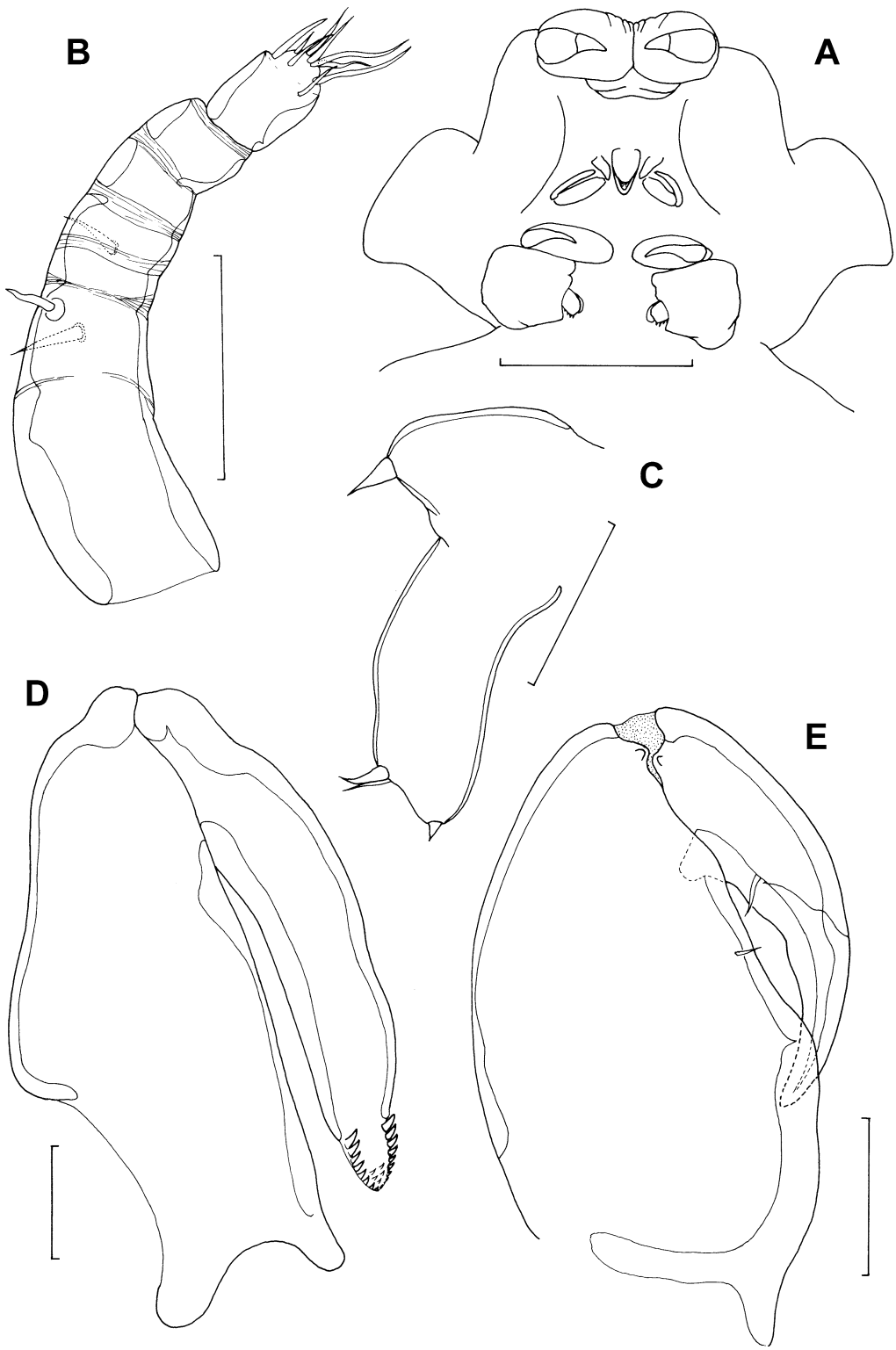

Fig. 2 *Sagum posteli* Delamare-Deboutteville & Nunes-Ruivo, 1954, female. A, cephalothorax, ventral view; B, antennule; C, maxillule, ventral view; D, maxilla, posterior view; E, maxilliped, posterior view. *Scale-bars*: A, 100 μm; B–E, 50 μm

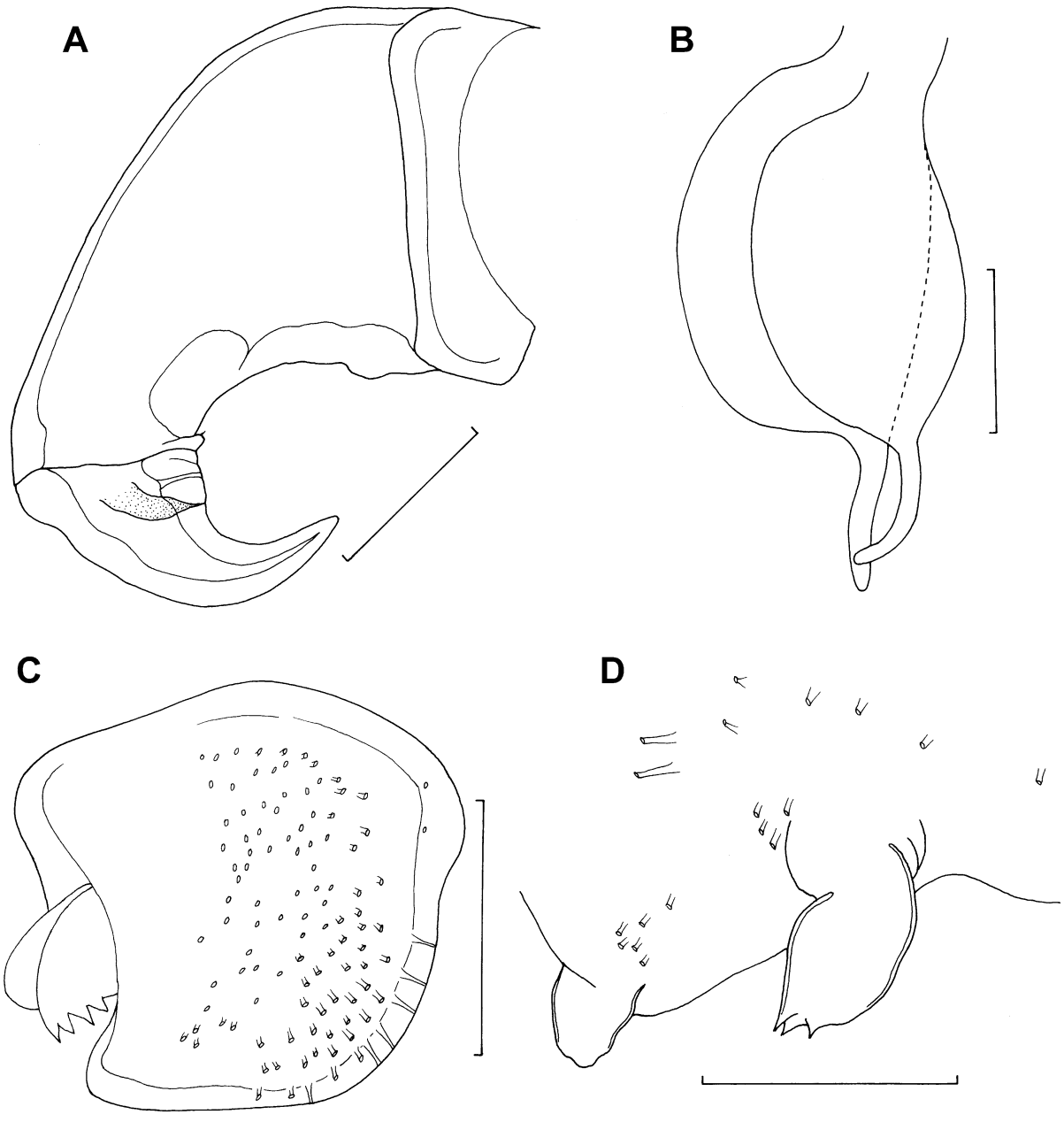

Fig. 3 *Sagum posteli* Delamare-Debouteville & Nunes-Ruivo, 1954, female. A, antenna, posterior view; B, leg 4; C, leg 1, ventral view, *in situ*; D, rami of leg 2, ventral view. *Scale-bars*: A,B, 0.5 mm; C,D, 100 μm

Maxilla (Fig. 2D) two-segmented, comprising proximal syncoxa (lacertus) and distal subchela formed from basis (brachium); basis ornamented with array of sharp denticles on inner surface at apex. Maxilliped (Fig. 2E) comprising robust corpus with small seta on medial surface and distal subchela; subchela comprising endopodal segment, partly separated from curved terminal claw by incomplete suture line armed with seta: surface of subchela ornamented with longitudinal striations (Fig. 4D).

Leg 1 ventrally located near posterior margin of cephalothorax (Fig. 2A), comprising inflated lobe of

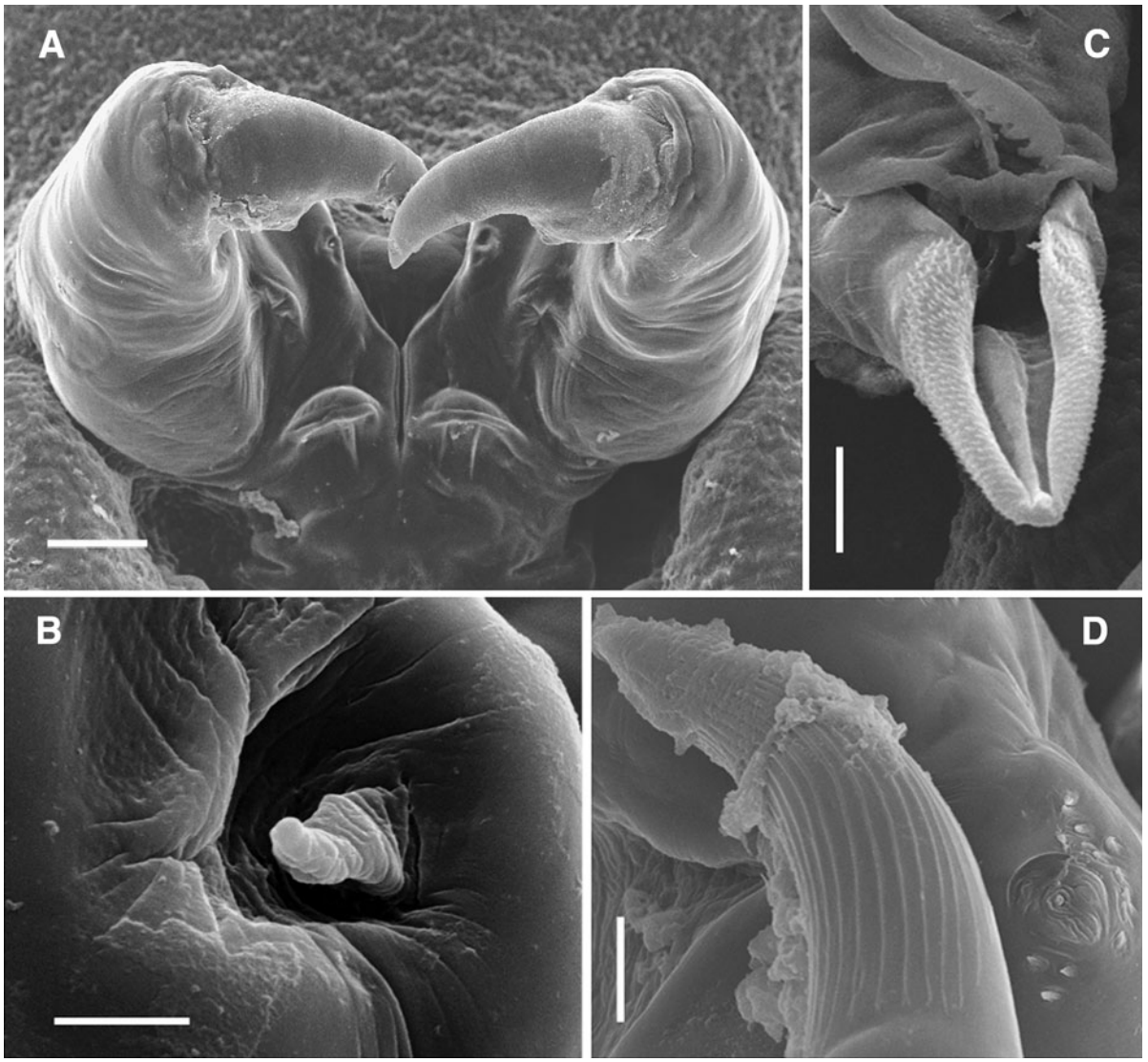

Fig. 4 Scanning electron micrographs of *Sagum posteli* Delamare-Deboutteville & Nunes-Ruivo, 1954, female. A, paired antennae, postero-ventral view; B, papilliform element on anteromedial margin of corpus of antenna; C, tip of mouth tube showing spinulate margins of labium and smooth margin of small labrum, displaced mandible blade also visible; D, subchela of maxilliped showing surface striations. *Scale-bars*: A, 100 μm; B, 5 μm; C,D, 20 μm

protopodal origin carrying both rami medially and therefore partly concealed in ventral view (Fig. 3C); protopod surface ornamented with hyaline points. Leg 1 biramous; exopod one-segmented, armed with four marginal spines; endopod one-segmented, tapering distally, apparently unarmed. Leg 2 inflated, with rami carried posteriorly on swelling derived from incorporated protopod (Fig. 1C); both rami one-segmented; exopod armed with three or four terminal spinous processes; endopod unarmed (Fig. 3D). Leg 3 biramous; endopodal lobe forming large lamella protruding postero-ventrally; exopodal lobes lamellate, protruding ventrally and fused in mid-line (Fig. 1B,C). Leg 4 (Fig. 3B) modified, biramous, with each ramus forming unsegmented lobe with lamellate proximal part and narrow distal section. Leg 5 represented by paired lobes on ventral surface of genital complex, bearing single laterally directed apical seta (Fig. 1D).

Male: Unknown.

Remarks

The Turkish material is identified as *S. posteli* on the basis of the general proportions of the body, the form of the fourth legs and the detailed structure of the second legs. The original description was based on females, but this species has remained poorly known since the cephalothoracic limbs of the female were never described. The figures provided in the original description indicate that the specimens had undergone post-mortem inflation, i.e. a swelling that is presumably induced by the intake of water. Such swelling is often observed in fixed material; it tends to splay out the third and fourth legs and grossly inflate the trunk, making comparison of shape with other material difficult.

The original record of *S. posteli* was from off the island of Goré, Senegal, in the eastern Atlantic (Delamare-Deboutteville & Nunes-Ruivo, 1954), and so the discovery of this species in the eastern Mediterranean represents a significant extension in the known geographical range of the parasite. It was collected from the same host fish, *Epinephelus aeneus*, off both Senegal and Turkey.

The genus *Sagum* Wilson, 1913

Sagum was established by Wilson (1913) to accommodate the type-species, *S. flagellatum* Wilson, 1913. Subsequently, Wilson (1922), in his revision of North American copepods belonging to the Dichelesthiidae, transferred *Lernanthropus angulatus* Krøyer, 1863 to *Sagum* as *S. angulatum* (Krøyer, 1863). A third species, *S. posteli* Delamare-Deboutteville & Nunes-Ruivo, 1954, was added by Delamare-Deboutteville & Nunes-Ruivo (1954). Yamaguti & Yamasu (1960) erected *Pseudolernanthropus* to accommodate their new species, *P. epinepheli* Yamaguti & Yamasu, 1960, and suggested including *L. petersi* van Beneden, 1857 in their new genus. Yamaguti (1963) maintained both these genera as valid but retained only the type-species, *S. flagellatum*, in *Sagum* and transferred all the remaining species to *Pseudolernanthropus*. Pillai & Sebastian (1967) resolved much of the confusion when, after re-examination of *P. epinepheli*, the type-species, concluded that the two genera were synonymous. At that time *Sagum* thus comprised *S. flagellatum*, *S. angulatum*, *S. petersi*, *S. posteli*, *S. texanum* Pearse, 1952 and *S. epinepheli* (Yamaguti & Yamasu, 1960).

The situation became more complex when Hewitt (1968) established a new genus, *Paralernanthropus* Hewitt, 1968 based on the type-species, *Lernanthropus foliaceus* Goggio, 1905. Hewitt attributed *L. foliaceus* to Goggio (1905) on the grounds that *L. foliaceus* Richiardi, 1878 was a *nomen nudum*. Hewitt (1968) also proposed the transfer of *S. petersi*, *S. posteli* and *S. texanus* to his new genus. In their phylogenetic analysis of the family, Ho & Do (1985) maintained *Sagum* as a valid genus, recognising both *Pseudolernanthropus* and *Paralernanthropus* as synonyms, although they did not comment on the placement of *L. foliaceus*. Ho et al. (2008) listed ten nominal species in the genus: *S. flagellatum*, *S. angulatum*, *S. petersi*, *S. posteli*, *S. texanum*, *S. epinepheli*, *S. vespertilio* Kabata, 1979, *S. enneacentri* Pillai, 1985, *S. poeyi* Ortiz, Lalana & Suarez, 2003 and *S. tuberculatum* Pillai, 1985, but did not include or mention *L. foliaceus*. Subsequently, the same authors (Ho et al., 2011) described a new species, *S. folium* Ho, Liu & Lin, 2011, but this time they explicitly included *S. foliaceum* in their list of valid species.

One additional complication is that the redescription of *S. epinepheli* provided by Pillai & Sebastian (1967) based on Indian material differs from the original description of Yamaguti & Yamasu (1960). The Indian material differs in the shape of the cephalothorax, in body proportions and in the relative length of the distal slender part of the rami of leg 4. In our view, there is significant doubt that the Indian material of Pillai & Sebastian (1967) is conspecific with *S. epinepheli* as described by Yamaguti & Yamasu (1960). The material of *S. epinepheli* in the collections of the Natural History Museum, London taken from a variety of serranid (epinepheline) hosts (see Justine et al., 2010, for details) conforms with the taxon described originally by Yamaguti & Yamasu (1960), as does the material from Taiwan redescribed as *S. epinepheli* by Ho et al. (2011). We consider it likely that the Indian material used by Pillai & Sebastian (1967) for their redescription is not conspecific with the *S. epinepheli* of Yamaguti & Yamasu (1960).

Not all these nominal species are valid. Ho et al. (2008) redescribed *S. vespertilio* on the basis of new material collected from Taiwan and relegated

Table 1 Known hosts for *Sagum* species

Sagum species	Host	Host family	Reference
S. angulatum	"*Serranus*" sp.	Serranidae	Krøyer (1863)
S. enneacentri	*Cephalopholis sonnerati* (Valenciennes) (as *Enneacentrus sonnerati*)	Serranidae	Pillai (1985)
S. epinepheli	*Epinephelus akaara* (Temminck & Schlegel)	Serranidae	Yamaguti & Yamasu (1960)
	Epinephelus awoara (Temminck)	Serranidae	Ho et al., 2011
	Epinephelus merra Bloch	Serranidae	Pillai (1985); Justine et al. (2010)
	Epinephelus chlorostigma (Valenciennes)	Serranidae	Justine et al. (2010)
	Epinephelus coeruleopunctatus (Bloch)	Serranidae	Justine et al. (2010)
	Epinephelus cyanopodus (Richardson)	Serranidae	Justine et al. (2010)
	Epinephelus morrhua (Valenciennes)	Serranidae	Justine et al. (2010)
	Epinephelus morrhua (Valenciennes)	Serranidae	Justine et al. (2010)
"*S. epinepheli*"	*Epinephelus* sp.	Serranidae	Pillai & Sebastian (1967)
S. flagellatum	*Epinephelus adscensionis* (Osbeck)	Serranidae	Wilson (1913)
S. foliaceus	*Ruvettus pretiosus* Cocco (as *Thyristes pretiosus*)	Gempylidae	Goggio (1905)
	Thyristes atun (Euphrasen)	Gempylidae	Hewitt (1968)
	Rexea solandri (Cuvier) (as *Jordanidia solandri*)	Gempylidae	Hewitt (1968)
	Acanthocybium solandri (Cuvier)	Scombridae	BMNH 1979.442-447
S. folium	*Paracaesio caerulea* (Katayama)	Lutjanidae	Ho et al., 2011
S. petersi	*Epinephelus fuscoguttatus* (Forsskål) (as *Serranus goliath*)	Serranidae	van Beneden (1857)
	Epinephelus lanceolatus (Bloch) (as *Promicrops lanceolatus*)	Serranidae	Kabata (1979)
S. posteli	*Epinephelus aeneus* (Geoffroy Saint-Hilaire)	Serranidae	Delamare-Deboutteville & Nunes-Ruivo (1954); Present account
S. texanum	*Lachnolaimus maximus* (Walbaum)	Labridae	Pearse (1952)
(as *S. poeyi*)	*Lachnolaimus maximus* (Walbaum)	Labridae	Ortiz et al. (2003)
(as *S. poeyi*)	*Mycteroperca bonaci* (Poey	Serranidae	Ortiz et al. (2003)
S. vespertilio	*Lethrinus nebulosus* (Forsskål)	Lethrinidae	Ho et al. (2008)
	Lethrinus fletus (Whitley)	Lethrinidae	Kabata (1979)
(as *S. tuberculatum*)	*Lutjanus* sp.	Lutjanidae	Pillai (1985)

S. tuberculatum as a junior synonym of *S. vespertilio*. The description of *S. poeyi* is difficult to interpret as the authors (Ortiz et al., 2003) only had two specimens at their disposal and have misunderstood the structure of the legs. We consider that there are no significant differences between *S. poeyi* and *S. texanum*. It is likely that folding of the basal section of the lobate rami of leg 4 has given rise to apparent differences in the form of these legs. Both descriptions, although inadequate by modern standards, show the presence of slight expansions on the antero-lateral corners of the trunk, which are lacking in other species. In addition, the type-host of both of these parasite species is the labrid *Lachnolaimus maximus* (Walbaum). We propose to treat *S. poeyi* as a junior subjective synonym of *S. texanum*.

Groupers (Serranidae, Epinephelinae) appear to be the primary host taxa for species of *Sagum*. Six of the ten valid species are found exclusively on epinepheline serranids (Table 1), and a seventh species also occurs on a serranid as well as on a labrid host. Two of the remaining three species occur on host species representing two families: *S. foliaceus* has been reported from gempylid hosts ranging from the Mediterranean to New Zealand waters, but material in the collections of the Natural History Museum,

London, was collected from a scombrid host, *Acanthocybium solandri*, taken off the coast of South Africa; and *S. vespertilio* has been reported from both lethrinid and lutjanid hosts. Finally, the recently described *S. folium* occurs on a lutjanid host.

Key to the species of *Sagum* (adult females)

1. Posterior trunk shield *c*.30% longer than head and anterior region of trunk combined; leg 4 conspicuous in dorsal view, both rami taper gradually towards tip……...…*S. foliaceus*
– Posterior trunk shield not more than 10% longer than head and anterior region of trunk combined; leg 4 visible dorsally or concealed beneath trunk shield; rami taper abruptly towards slender distal part……2
2. Posterior trunk shield large, expanding in width posteriorly to reach maximum near posterior margin……*S. folium*
– Posterior trunk shield only as wide as or narrower than anterior region of trunk……3
3. Cephalothorax comprises about one third of total body length (excluding leg 4); anterior part of trunk about as long as posterior trunk shield; tips of leg 4 extend beyond rear margin of posterior trunk shield and are readily visible in dorsal view……..…4
– Cephalothorax not more than one third to less than a quarter of total body length; anterior part of trunk shorter than posterior trunk shield (measured along dorsal mid-line); tips of leg 4 concealed and not visible in dorsal view or extending beyond rear margin of posterior trunk shield……...…5
4. Lateral margins of cephalothorax evenly convex; posterior trunk shield wider than long; leg 3 with single slender tapering lobe visible in dorsal view……*S. petersi*
– Lateral margin of cephalothorax with pointed posterior lobe; posterior trunk shield longer than wide……*S. enneacentri*
5. Cephalothorax with large, wing-like, triangular lateral expansions bearing linear anterolateral margins……*S. vespertilio*
– Cephalothorax with rounded or pointed lateral lobes……..…6
6. Posterolateral lobes of anterior trunk large, extend posteriorly almost to rear margin of posterior trunk shield; tips of leg 4 lobes extend beyond rear margin of posterior trunk shield, visible in dorsal view……..…*S. flagellatum*
– Posterolateral lobes of anterior trunk extend about to middle of posterior trunk shield; tips of leg 4 concealed beneath posterior trunk shield or only just visible and extending beyond rear margin…... ……...…7
7. Lobate rami of leg 4 each subdivided into broad proximal part and slender distal part, approximately equal in length……..…8
– Lobate rami of leg 4 subdivided into broad proximal part and much shorter slender distal part……9
8. Lateral margins of cephalothorax rounded; anterior part of trunk with slight expansions on anterolateral corners……..……*S. texanum*
– Lateral margins of cephalothorax gradually widen posteriorly, terminating in recurved posterior points……..…*S. angulatum*
9. Lateral margins of cephalothorax extended into ventrally directed folds with rounded posterior extremities……..……*S. posteli*
– Lateral margins of cephalothorax produced laterally into lobes with pointed posterior extremities……..…*S. epinepheli*

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