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CALIGUS TURKIYENSIS N. SP. (COPEPODA: CALIGIDAE) ON THE FLATHEAD GREY MULLET, *MUGIL CEPHALUS* (LINNAEUS) (MUGILIFORMES: MUGILIDAE) FROM THE SEA OF MARMARA, TURKEY

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CALIGUS
MUGIL
CHELON
PARASITIC COPEPOD
SEA OF MARMARA

ABSTRACT.- *Caligus turkiyensis* n. sp. is described from the body surface and fins of the flathead grey mullet, *Mugil cephalus* Linnaeus, 1758, collected in the Sea of Marmara in Turkey. The new species is easily distinguished from its congeners by the ratio of genital complex length/abdomen length, number of segments in abdomen, length of tines in the sternal furca, number of teeth on the mandible, position of the posterolateral corners of the genital complex relative to the abdomen, status of the recurved terminal claw of the antenna and postantennal process, ratio of length and anterior margin of the maxillule endopodite, process on myxal surface of maxilliped, ratio of first/third spine on fourth leg and existence of denticles on first spine of fourth leg in the female; total body length, process on myxal surface of maxilliped, number of plates and spine at terminal segment of antenna in the male. This study also includes records of *Caligus apodus* (Brian 1924) and *Caligus pageti* Russel, 1925 on two mugilid species from the Sea of Marmara, Turkey. The Sea of Marmara is considered as a new locality for *C. pageti.*

INTRODUCTION

Members of the Caligidae family are ectoparasite copepods on fish. There are 269 valid species listed in the genus *Caligus*, belonging to the family Caligidae (Walter & Boxshall 2024). Species belonging to *Caligus* are known as sea lice. These parasites are of global importance, because sea lice cause high levels of mortality as well as catastrophic losses in salmonid aquaculture. As a result, the direct and indirect effects of fish lice are economic losses in aquaculture (Johnson *et al.* 2004).

The number of *Caligus* species in the Mediterranean increased to 32, after the record of C*aligus tunisiensis* Hamdi, Benmansour, Zouari-Tlig, Kamanli, Özak, Boxshall, 2021 on *Serranus scriba* (Linnaeus, 1758) from the Mediterranean Sea. So far, 20 species of *Caligus* have been reported from the fishes of the Aegean Sea and Mediterranean Sea of Turkey: *Caligus adenensis* Özak, Sakarya & Boxshall 2019, *Caligus apodus* (Brian 1924), *Caligus bonito* C. B. Wilson 1905, *Caligus brevicaudatus* A. Scott 1901, *Caligus dakari* van Beneden 1892, *Caligus diaphanus* von Nordmann 1832, *Caligus lagocephali* Pillai 1961, *Caligus lichiae* Brian 1906, *Caligus ligusticus* Brian 1906, *Caligus macrurus* Heller 1865, *Caligus minimus* Otto, 1821, *Caligus mulli* Rodrigues, Özak, Silva & Boxshall 2018, *Caligus pageti* Russel 1925, *Caligus pelamydis* Krøyer, 1863, *Caligus quadratus* Shiino, 1954, *Caligus scribae* Essafi, Cabral & Raibaut 1984, *Caligus solea* Demirkale, Özak, Yanar & Boxshall 2014, *Caligus temnodontis* Brian 1924 and *Caligus vexator* Heller,1865. Five species of *Caligus* are known from the Sea of Marmara: *C. apodus*, *C. bonito*, *C. diaphanus*, *Caligus minimus* and *Caligus* zei Norman & T. Scott 1906 (Özak 2020).

Eighteen species of *Caligus* from *Mugil cephalus* Linnaeus, 1758 are listed in the world (Table I, WoRMS 2024), but only four of them are known on *M. cephalus* from the Mediterranean Sea. These species are *C. apodus*, *C. minimus*, *C. mugilis* and *C. pageti* (see Raibaut *et al*. 1971, Raibaut & Ben Hassine 1977, Raibaut *et al.* 1998, Kabata 2003).

This paper describes a new species, *Caligus turkiyensis* n. sp. from the body surface and fins of the flathead grey mullet, *M. cephalus*, collected in the Sea of Marmara of Turkey. Two other *Caligus* species were identified in this survey: *Caligus apodus* and *Caligus pageti* on the body surface and fins of *Chelon auratus* (Risso, 1810) and *M. cephalus* from the Sea of Marmara, Turkey.

MATERIALS AND METHODS

One hundred and thirty specimens of the flathead grey mullet, *Mugil cephalus* and 63 of the golden grey mullet, *Chelon auratus* were caught by rod and line from Bandırma Bay, Turkey (the Sea of Marmara) in 2022. The parasites collected were fixed in 70 % ethanol. Some of the specimens were later cleared in lactic acid for 2 h before dissection of the appendages. The samples were dissected using an Olympus SZH10 and a Wild M5 stereomicroscope. The appendages were mounted on slides in a glycerin-gelatine mounting medium following Pritchard & Kruse (1982). The drawings of appendages were made with the aid of a drawing tube (Olympus® BH-DA). Microscope images were drawn on tracing paper, and the drawings were scanned and digitized. Additionally, microphotographs were taken with the aid of a Canon camera (EOS 1100D) connected to an Olympus CH30 phase contrast microscope. The scientific names and synonyms for parasites and hosts were checked with WoRMS (2024), and Froese & Pauly (2024), respectively. The nomenclature of copepod body parts follows Boxshall (1990) and Huys & Boxshall (1991). Samples of *C. turkiyensis* n. sp. in this study were compared with samples of *Caligus minimus* previously collected from Köyceğiz Dalyan Lagoon (Figs. 2, 6). Type and voucher specimens are deposited in the Zoology Collection of the İstanbul University, Faculty of Science, İstanbul, Turkey.

RESULTS

In this study, three species of *Caligus* were identified: *Caligus apodus*, *Caligus pageti* and *Caligus turkiyensis* n. sp.

Phylum Arthropoda von Siebold, 1848
Subphylum Crustacea Brünnich, 1772
Class Copepoda Milne Edwards, 1840
Order Siphonostomatoida Burmeister, 1835
Family Caligidae Burmeister, 1835
Genus Caligus Müller O.F., 1785

***Caligus apodus* (Brian, 1924)** (Fig. 1)
Host: *Chelon auratus*(Risso, 1810) (Mugilidae) (n = 63)
Locality: Bandırma Bay (Balıkesir, Sea of Marmara, Turkey; 40°21'12.8" N 27°58'04.7" E); depth range: 1-3 m
Locality properties: A region where flows the sewage waters of Bandırma City
Site on host: body surface, pectoral, ventral and caudal fins
Prevalence of infection: 21 %, Mean intensity: 1.3
Material examined: 1 female and 1 male deposited in the Zoology Collection of the Istanbul University, Faculty of Science (IUSHM 20231007-07, IUSHM 20231007-08)

Adult female: Body (Fig. 1a) consists of a caligiform cephalothorax shield, a fourth pedigerous somite, a genital complex, and 1-segmented abdomen with paired caudal rami. Total body length 3.72 mm (3.33-4.26, n=4) caudal rami, excluding setae. Dorsal cephalothoracic shield is subcircular and slightly longer 1.74 mm (1.57-1.91) than wide 1.63 mm (1.40-1.81). Fourth pedigerous somite wider 0.37 mm (0.27-0.42) than long 0.21 mm (0.15-0.25), distinctly separated from the cephalothorax and genital complex. Genital complex subcircular, is wider 1.07 mm (0.84-1.23) than long 0.90 mm (0.73-1.12), about 1.3 times longer than the abdomen. Abdomen subrectangular and elongated, 1-segmented, longer 0.69 mm (0.66-0.72) than wide 0.37 mm (0.29-0.42). Caudal ramus subrectangular, slightly longer 0.19 mm (0.14-0.31) than wide 0.15 mm (0.11-0.20), each armed with six plumose setae. Egg sac long 2.39 mm (1.98-3.21), wide 0.33 mm (0.31-0.42). Setal and spinal formula of 1-4 legs are given in Table II.

Adult male: Body (Fig. 1b) consists of a caligiform cephalothorax shield, fourth pedigerous somite, genital complex and 1-segmented abdomen with paired caudal rami. Total body length 3.57 mm, (3.52-3.62, n = 2) caudal rami, excluding setae. Dorsal cephalothoracic shield subcircular, slightly longer 1.91 mm (1.90-1.92) than wide 1.72 mm (1.70-1.74). Fourth pedigerous somite wider 0.42 mm (0.41-0.42) than long 0.22 mm (0.21-0.22), distinctly separated from the cephalothorax and genital complex. Genital complex subcircular, is slightly wider 0.71 mm (0.7-0.72) than long 0.61 mm (0.59-0.62), about as long as the abdomen. Abdomen subrectangular 1-segmented, longer 0.62 mm (0.60-0.63) than wide 0.32 mm (0.31-0.32). Caudal ramus subrectangular, slightly longer 0.23 mm (0.22-0.23) than wide 0.12 mm (0.11-0.12) and each armed with six plumose setae.

Remarks: Brian (1924) first described *C. apodus* (as syn *Pseudocaligus apodus*) on *M. cephalus* from Mauritania. This species is easily distinguished from the other caligid species by the absence or presence of the vestigial fourth leg in female and male samples. Ben Hassine (1983) mentioned the presence of vestigial fourth legs in both females and males of *C. apodus* from Tunisia. Özak *et al*. (2013) did not observe a vestigial fourth leg in female samples from Turkey. They also found a minute, rod-like trace of a possible fourth leg in one of the two females in Brian's (1935) samples from Italy. No evidence of the fourth leg in female individuals was found in the present study.

Özak *et al*. (2013) also compared male samples of *C. apodus* from Turkey and Brian's (1935) samples from Italy. Özak *et al*. (2013) found three unequal and spiniform elements at the apex in the samples from Turkish Mediterranean Sea Coasts and two spiniform terminal elements in Italian material. The fourth leg with three terminal spiniform elements in the male samples (Fig. 1c) in this study is also compatible with those of Özak *et al*. (2013).

The total body length of females in this study was smaller than in Brian's (1935) length of

Caligus Species	Locality	Reference
Caligus apodus (Brian, 1924)	Italy	Brian (1935)
Caligus pageti Russell, 1925	Egypt	Russell (1925)
Caligus minimus Otto, 1821	British Waters	Kabata (2003)
Caligus mugilis Brian, 1935	Italy	Brian (1935)
Caligus bonito Wilson C.B., 1905	North America	Cited by Paperna & Overstreet (1981)
Caligus curtus Müller O.F., 1785	Beaufort, North Carolina, USA	Wilson (1908) cited by Parker *et al.* (1968)
Caligus engraulidis Barnard, 1948	Lake St.Lucia, South Africa	Grobler (2004) cited by Dippenaar (2005)
Caligus epidemicus Hewitt, 1971	Mitchell River, Victoria, Australia	Hewitt (1971)
Caligus irritans Heller, 1865	Biscayne Bay, Florida	Skinner (1975)
Caligus mutabilis Wilson C.B., 1905	Palmyra Atoll, Central Pacific	Soler-Jiménez *et al.* (2019)
Caligus orientalis Gusev, 1951	Lake Mokoto	Urawa & Kato (1991)
Caligus platytarsis Bassett-Smith, 1898	Young off Heron Island, Queensland	Kabata (1965)
Caligus praetextus Bere, 1936	North America	Bere (1936)
Caligus punctatus Shiino, 1955	North America	Cited by Paperna & Overstreet (1981)
Caligus rotundigenitalis Yü, 1933	Taiwan	Ho & Lin (2004)
Caligus rufimaculatus Wilson C.B., 1905	Biscayne Bay, Florida	Skinner (1975)
Caligus schistonyx Wilson C.B., 1905	North America	Cited by Paperna & Overstreet (1981)
Caligus schlegeli Ho & Lin, 2003	Dongshih Fishing Port in Chiayi County	Ho & Lin (2003)

Table I.- *Caligus* species reported from *Mugil cephalus* in the world

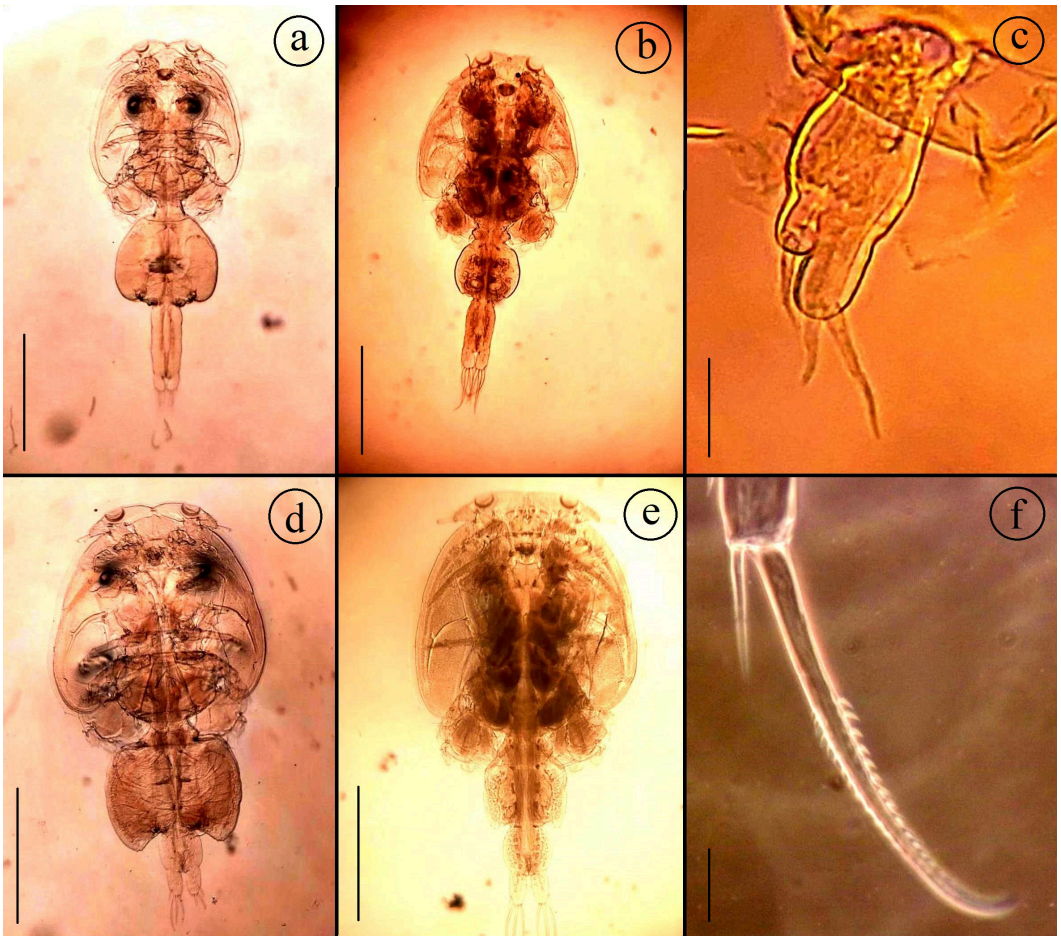

Fig. 1.- *Caligus apodus*, **a:** Female (1.29 mm); **b:** Male (1.17 mm); **c:** Male fourth leg (0.4 mm); *Caligus pageti*, **d:** Female (1.33 mm); **e:** Male (1.4 mm); **f:** Female fourth leg (0.5 mm).

4.3-5.00 mm and Özak *et al*.'s (2013) of 4.30 mm. The total body length of males in this study was greater than Özak *et al*.'s (2013) of 3.19 mm and smaller than in Brian's (1935) of 3.19-4.00 mm.

***Caligus pageti* Russel, 1925** (Fig. 1)

Host: *Mugil cephalus* Linnaeus, 1758 (Mugilidae) (n = 130)

Locality: Bandırma Bay (Balıkesir, Sea of Marmara, Turkey; 40°21'12.8"N 27°58'04.7"E); depth range: 1-3 m

Locality properties: A region where flows the sewage waters of Bandırma City

Site on host: body surface, pectoral, ventral and caudal fins

Prevalence of infection: 10 %, Mean intensity: 1.2

Material examined: 1 female and 1 male deposited in the Zoology Collection of the Istanbul University, Faculty of Science (IUSHM 20231007-09, IUSHM 20231007-10)

Adult female: Body (Fig. 1d) consists of a caligiform cephalothorax shield, a fourth pedigerous somite, a genital complex and 1-segmented abdomen with paired caudal rami. Total body length 4.17 mm (3.42-5.07, n = 4). Dorsal cephalothoracic shield subcircular, is slightly longer 2.40 mm (2.02-2.93) than wide 2.28 mm (1.87-2.81). Fourth pedigerous somite wider 0.64 mm (0.51-0.81) than long 0.25 mm (0.22-0.29), distinctly separated from the cephalothorax and genital complex. Genital complex subrectangular, wider 1.35 mm (0.91-1.71) than long 0.89 mm (0.62-1.12); about 2.3 times longer than the abdomen, and with slightly lobate posterolateral corners of genital complex and extending to middle of abdomen. Abdomen subrectangular, 1-segmented, slightly wider 0.44 mm (0.38-0.51) than long 0.39 mm (0.35-0.46). Caudal ramus subrectangular, longer 0.24 mm (0.21-0.27) than wide 0.16 mm (0.12-0.20), each armed with six plumose setae. Egg sac long 2.79 mm (1.72-3.62), wide 0.39 mm (0.31-0.42). Setal and spinal formula of 1-4 legs are given in Table II.

Adult male: Body (Fig. 1e) consists of a caligiform cephalothorax shield, a fourth pedigerous somite, a genital complex and 1-segmented abdomen with paired caudal rami. Total body length 4.49 mm (4.21-4.63, n = 3). Dorsal cephalothoracic shield subcircular, slightly longer 2.63 mm (2.41-2.75) than wide 2.57 mm (2.31-2.72). Fourth pedigerous somite, wider 0.66 mm (0.61-0.69) than long 0.32 mm (0.31-0.33), distinctly separated from the cephalothorax and genital complex. Genital complex subcircular, wider 0.98 mm (0.91-1.02) than long 0.70 mm (0.67-0.72), about 1.3 times longer than abdomen. Abdomen subrectangular and 1-segmented, slightly wider 0.55 mm (0.51-0.61) than long 0.52 mm (0.51-0.52). Caudal ramus subrectangular, longer 0.32 mm (0.31-0.34) than wide 0.22 mm (0.22-.0.24), each armed with six plumose setae.

Remarks: *Caligus pageti* was first described on *M. cephalus* from Egypt by Russel (1925). The most distinguishing characteristic of *C. pageti* is the fourth leg, which is serrated to middle of inner and outer margins of fourth leg. The fourth leg is 3-segmented, with a protopodal segment and 2-segmented exopodal segment; protopodal segment with a plumose first exopodal segment with outer spine; second exopodal segment with long outer apical spine and one subapical spine about one-third the length of the apical spine; long apical spine serrated to the middle of inner and outer margins (Fig. 1f).

***Caligus turkiyensis* n. sp.** (Figs. 2-6)

Type host: *Mugil cephalus* Linnaeus, 1758(Mugilidae) (n = 130)

Locality: Bandırma Bay (Balıkesir, Sea of Marmara, Turkey; 40°21'12.8"N 27°58'04.7"E);

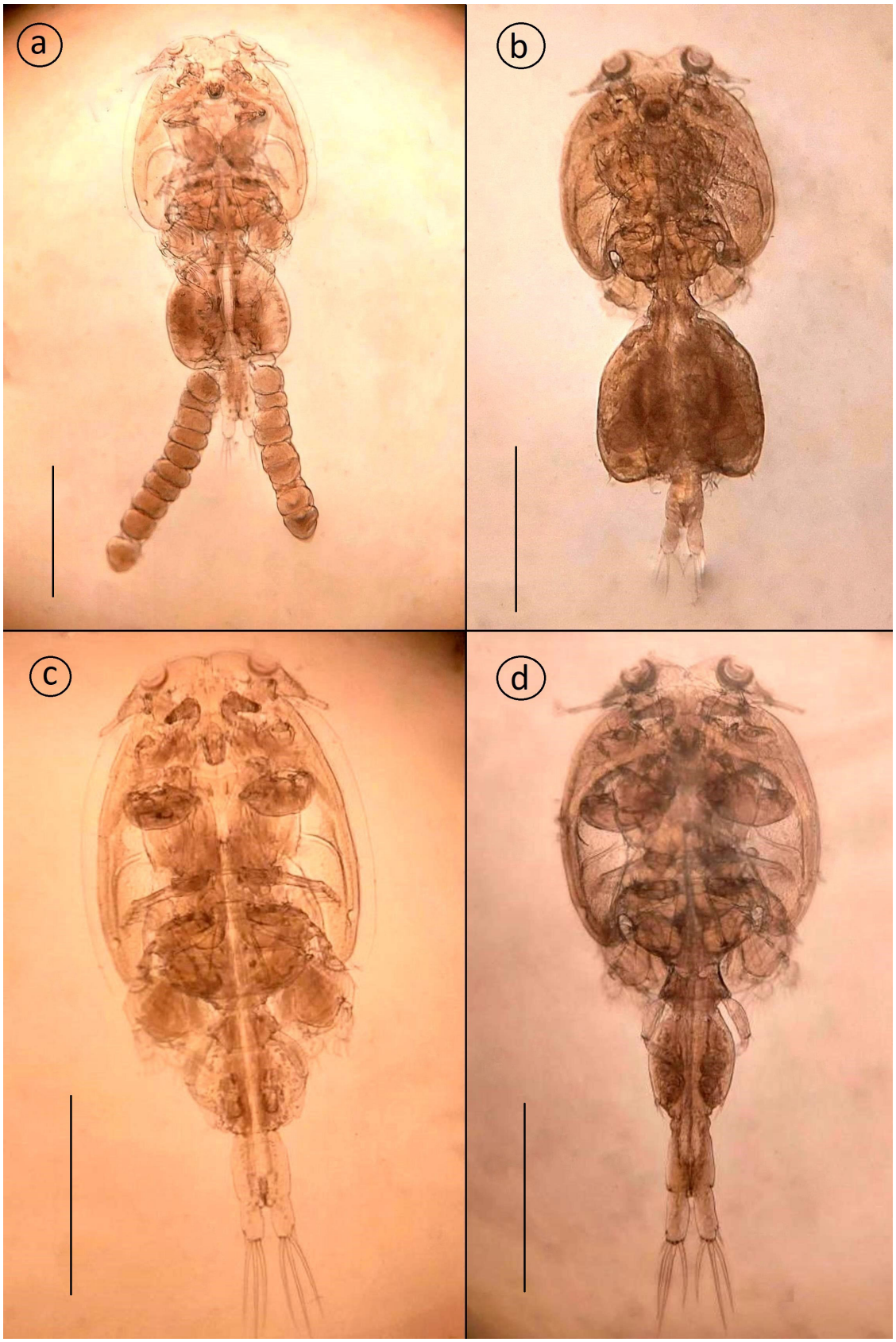

Fig. 2. *Caligus turkiyensis* n. sp. **a:** Female (1.29 mm); **c:** Male (1.16 mm); *Caligus minimus*, **b:** Female (1.62 mm); **d:** Male (1.41 mm).

depth range: 1-3 m

Locality properties: A region where flow the sewage waters of Bandırma City

Site on host: body surface, fins

Prevalence of infection: 22 %, Mean intensity: 1.1

Type Material: Holotype female and paratype male deposited in the Zoology Collection of the Istanbul University, Faculty of Science (IUSHM 20231007-03, IUSHM 20231007-04)

Etymology: The species name refers to Turkey, close to where the material was collected.

Description

Adult female: Cephalothorax subcircular, dorsoventrally flattened, lateral zones of dorsal cephalothoracic shield associated with well-developed marginal membranes. Body consists of a caligiform cephalothorax shield, a fourth pedigerous somite, a genital complex and an indistinctly 2-segmented abdomen with paired caudal rami. Total body length 3.79 mm (3.13-4.61, n = 7) (Fig. 2a, 3a). Dorsal cephalothoracic shield subcircular, longer at 1.82 mm (1.52-2.01) than wide 1.61 mm (1.34-1.73). Fourth pedigerous somite is wider at 0.46 mm (0.24-0.61) than long 0.23 mm (0.14-0.32), distinctly separated from the cephalothorax and genital complex. Genital complex subcircular, is slightly wider at 1.04 mm (0.77-1.52) than long 0.94 mm (0.74-1.31), about 1.6 times longer than the abdomen and with nonlobate posterolateral corners of genital complex. Abdomen subrectangular, indistinctly with two somites, first abdominal somite slightly wider at 0.31 mm (0.21-0.41) than long 0.18 mm (0.12-0.22), anal somite longer at 0.41 mm (0.28-0.48) than wide 0.33 mm (0.28-0.42). Egg sac 2.11 mm (1.82-2.51) long by 0.36 mm (0.31-0.42) wide.

Antennule (Fig. 3b) 2-segmented; proximal segment distinctly larger than distal, armed with 24 setae; distal segment armed with isolated subterminal seta on posterior margin and 11 naked setae plus two aesthetascs around the apex. Antenna (Fig. 3f, 6e) uniramous, 3-segmented; proximal segment subrectangular with rounded margins and a short process; middle segment subrectangular and armed with a large corrugated adhesion pad on the dorsal surface; terminal segment forming a recurved claw armed with a seta near the middle area and posterior margin. Post-antennal process (Fig. 3f, 6g) well-developed, slender and slightly curved, ornamented with two trisensillate papillae on the basal part and a single similar trisensillate papilla on the adjacent ventral cephalothoracic surface near the base of the post-antennal process. Mandible (Fig. 3c, 6m) stylet-like, armed with 13 marginal teeth on inner side near the apex. Maxillule (Fig. 3h, 6k) comprising an anterior papilla bearing three naked setae (one medial long seta and two lateral small setae), and an anterior process with folding, and posterior process slender with rounded margin. Maxilla (Fig. 3g) 2-segmented and brachiform; proximal segment (lacertus) unarmed; distal segment (brachium) slender, bearing subterminal hyaline membrane on the inner margin plus short canna and long calamus distally. Maxilliped (Fig. 3e, 6a) subchelate, protopodal segment (corpus) elongate and bearing a slight expansion on myxal surface; distal subchela representing endopodal segments plus claw; small seta at the concave margin of claw base. Sternal furca (Fig. 3d, 6c) with subrectangular box, elongated and parallel tines with little divergence. Leg 1 (Fig. 4a) biramous with sympods joined by a slender intercoxal sclerite; sympod with inner and outer plumose seta, plus a setule; and endopod represented by a process on the posterior margin of basis, bearing two-minute vestigial setae on the apex. Exopod 2-segmented, with first exopodal segment robust, about 2.7 times longer than wide, armed with a small outer spine at the distal corner and ornamented with a row of setules along the mid-section of the posterior margin. Distal exopodal segment with three plumose setae

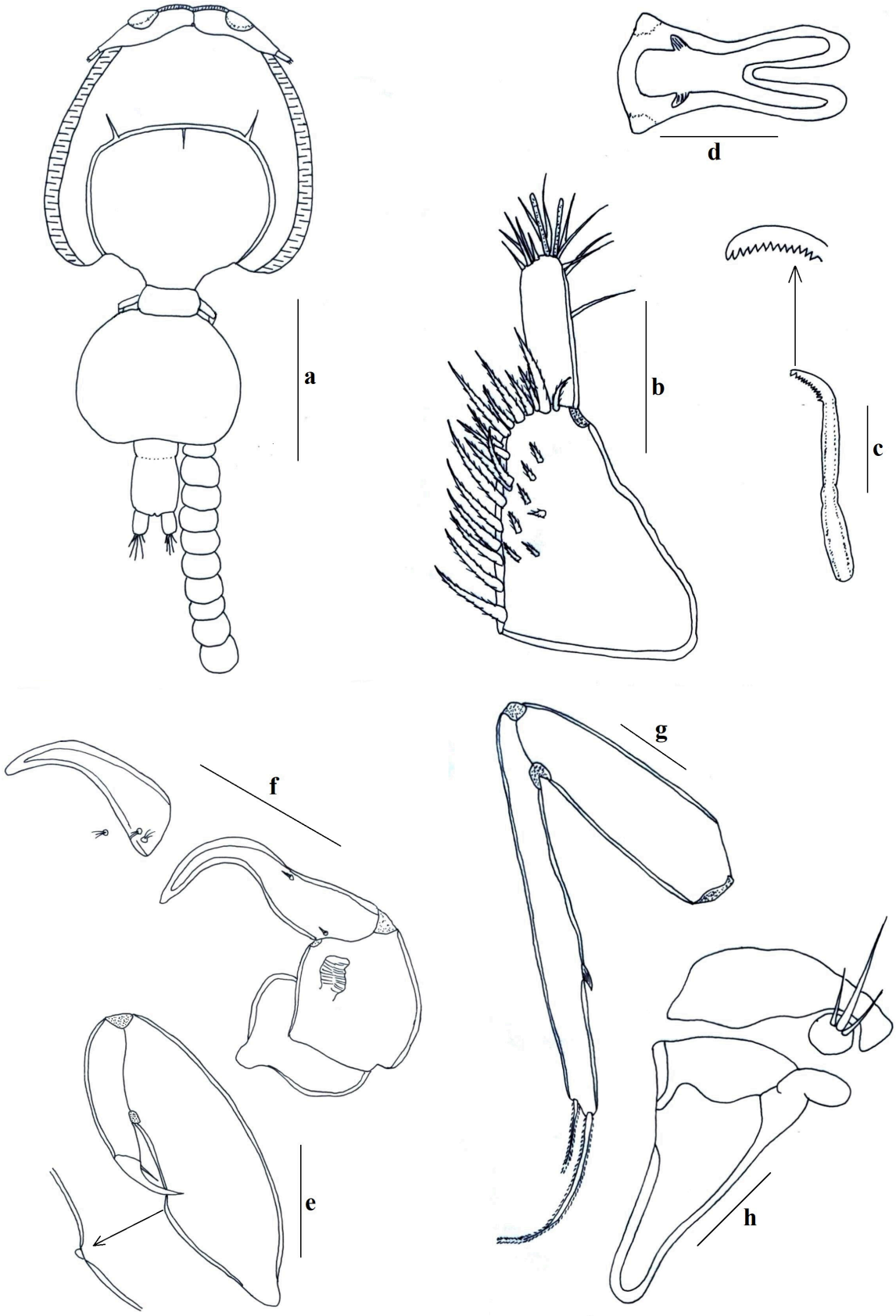

Fig. 3. *Caligus turkiyensis* n. sp. **a:** Female (1.29 mm); **b:** Antennule (0.12 mm); **c:** Mandible (0.075 mm); **d:** Sternal furca (0.10 mm); **e:** Maxilliped (0.11 mm); **f:** Antenna and post-antennal process (0.16 mm); **g:** Maxilla (0.09 mm); **h:** Maxillule (0.04 mm).

posteriorly plus four distal margin elements; spine 1 (outermost) and seta 4 smooth and longer than spines 2-3; spines 2 and 3 about equal in length, both lacking accessory process and arcuated with blunt ends. Leg 2 (Fig. 4b) biramous, with distinct coxa and basis; coxa short, bearing a long plumose inner seta and a sensillium on the ventral surface; basis armed with a short naked seta on the outer distal corner plus extensive marginal membrane along the posterior margin and a sensillium near the mid-length of the anterior margin. Exopod 3-segmented: first exopodal segment with inner plumose seta, an outer spine, extending to the middle of the third exopodal segment and with a row of setules on the inner margin; the second exopodal segment is the smallest, with an inner plumose seta and an outer distal spine and not extending across to the anterior margin of the third segment. Third exopodal segment with three outer spines and five inner plumose setae; first spine simple and smallest; second spine slightly longer than first spine and third spine with an outer marginal membrane and fine setules along the inner margin. Endopod 3-segmented; first endopodal segment subrectangular, armed with an inner plumose seta and ornamented with a row of setules along the outer margin; second segment elongated, armed with two inner plumose setae plus ornamented with a row of setules along the outer margin; third segment smallest, with six plumose setae. Leg 3 (Fig. 4c) protopodal part flattened and joined by plate-like intercoxal sclerite, forming an apron ornamented with marginal membrane posteriorly and along the lateral margin anterior to the exopod: bearing inner plumose seta at the junction with intercoxal plate and an outer plumose seta dorsal to the base of the exopod; sensillae located adjacent to the inner coxal seta and adjacent to the origin of endopod. Exopod 3-segmented: first segment with a large, recurved outer spine; a hyaline flap and sensillium along the corner of spine; second segment with an outer spine, inner plumose seta and setules along outer margin; the third segment with three outer spines (third spine slightly longer than the other two) and four short plumose setae. Endopod 2-segmented: first segment is armed with a long inner plumose seta; second segment is armed with six plumose setae, ornamented with rows of setules along the outer margin. Leg 4 (Fig. 4d, 6o) uniramous. Protopodal segment with an outer seta derived from the basis. Exopod 2-segmented; first segment bearing a short, slender, outer distal spine, not extending to the middle part of second exopodal segment; second segment with three apical spines increasing in length from outer to inner; first spine slightly shorter than second and third spine three times as long as. Leg 5 (Fig. 4e) is represented by three plumose setae. Setal and spinal formula of 1-4 legs are given in Table II. Caudal ramus (Fig. 4f) subrectangular, longer 0.19 mm (0.13-0.27) than wide 0.14 mm (0.10-0.25), each armed with three distal setae the longest on the outer margin, a median size seta, and other the two located opposed, and with a row of setules on inner margin.

Adult male: Cephalothorax subcircular, dorsoventrally flattened, lateral zones of dorsal cephalothoracic shield associated with well-developed marginal membranes. Body consists of a caligiform cephalothorax shield, a fourth pedigerous somite, a genital complex and 1-segmented abdomen with paired caudal rami. Total body length 3.67 mm (3.30-4.69, n = 7) (Fig. 2c, 5a). Dorsal cephalothoracic shield subcircular, is slightly longer 2.12 mm (1.82-2.71) than wide 1.75 mm (1.52-2.22). Fourth pedigerous somite at wider 0.49 mm (0.41-0.61) than long 0.29 mm (0.21-0.35), distinctly separated from the cephalothorax and genital complex. Genital complex subcircular, is slightly at wider 0.69 mm (0.56-0.92) than long 0.56 mm (0.46-0.72), and about 1.2 times longer than abdomen. Abdomen subrectangular, 1-segmented, longer at 0.46 mm (0.41-0.60) than wide 0.34 mm (0.30-0.42). Caudal

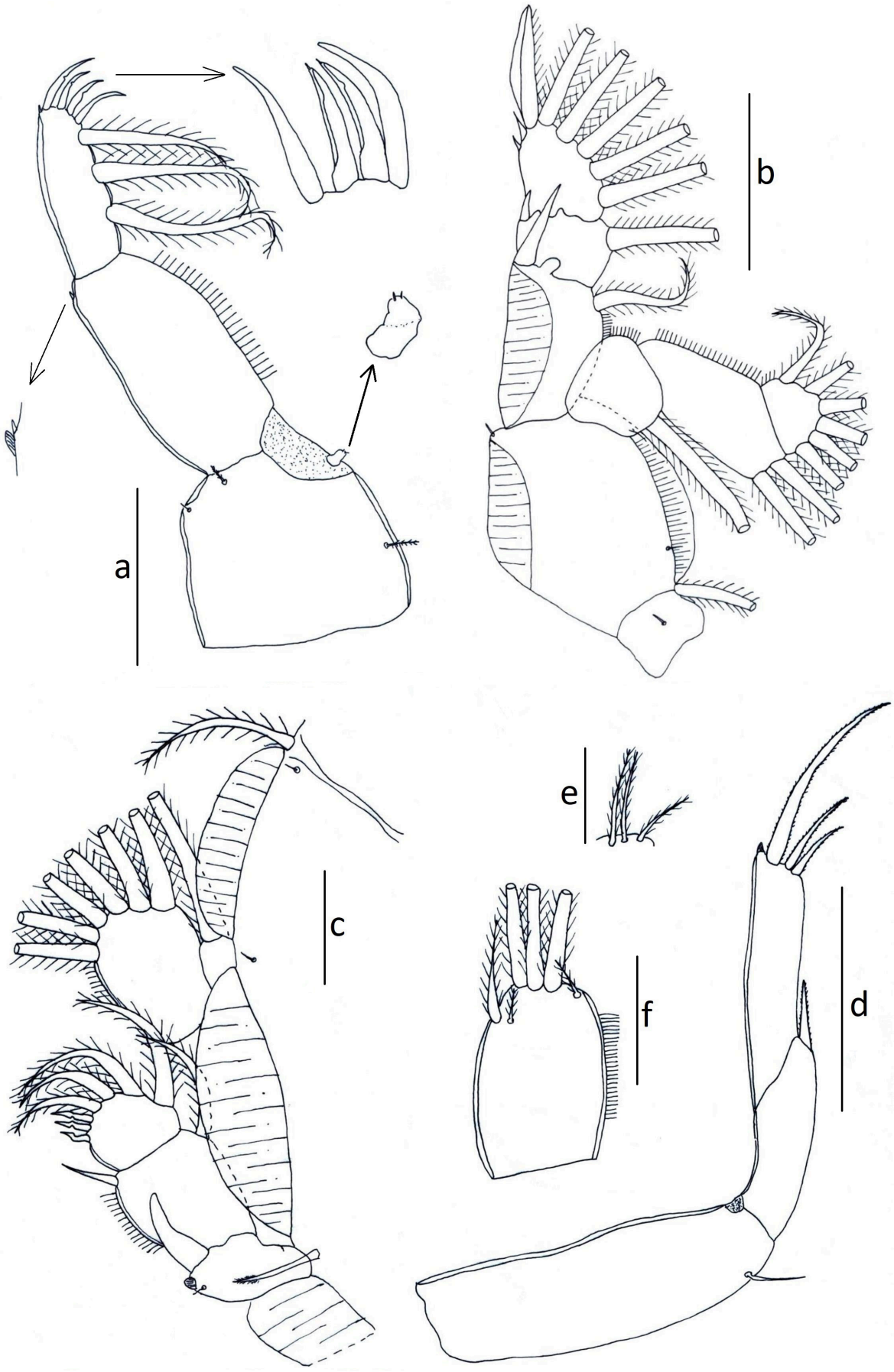

Fig. 4. - *Caligus turkiyensis* n. sp. **a:** First leg (0.18 mm); **b:** Second leg (0.25 mm); **c:** Third leg (0.11 mm); **d:** Fourth leg (0.23 mm); **e:** Fifth leg (0.04 mm); **f:** Caudal ramus (0.13 mm)

ramus subrectangular, longer at 0.23 mm (0.20-0.31) than wide 0.13 mm (0.11-0.22), each armed with six plumose setae. Antennule, mandible, post-antennal process and maxilla as in female. Maxilliped (Fig. 5b, 6i) protopod (corpus) is slightly swollen and armed with one small process at distal part and one big process as bifid at posterior part of myxal surface opposing tip of subchela; distal subchela armed with a short seta at the concave margin of claw base and a spine at posterior margin. Antenna (Fig. 5c) 3-segmented; proximal segment elongated and unarmed; middle segment reflexed, swollen proximally, with corrugated adhesion pads on medial and distal surfaces; distal segment with four plates on trifid direction and with basal seta. Maxillule (Fig. 5d) comprising an anterior papilla bearing three naked setae (one long and two small) and reduced posterior process. Legs 1 to 4, as in female. Leg 5 and 6 (Fig. 5e) are represented by three plumose setae and a minute spine, respectively.

Remarks: The report of *C. mugilis* from *M. cephalus* caught in Bandırma Bay (Sea of Marmara) by Alaş & Öktener (2017) is erroneous according to Özak (2020) for the following reasons: the female had an abdomen as long as the genital complex; the female maxilliped had a distinct, subtriangular myxal process; the posterolateral corners of the genital complex were indistinctly lobate and did not extend beyond the posterior margin of the genital complex. This study provided an opportunity to collect and examine the specimens of Alaş & Öktener (2017) again. The morphology of the new species appears to have the closest similarity to the four species *Caligus curtus* Müller O.F., 1785, *Caligus dicentrarchi* Cabral & Raibaut, 1986, *C. minimus* and *C. mugilis* (Table IV). *Caligus mugilis* was described for the first time from the mucous membrane of the mouth of *M. cephalus* from Portoferraio, Italy by Brian (1935), but he considered it to be a subspecies of *Caligus minimus* and named it as *Caligus minimus* var. n. *mugilis*. Later, Raibaut & Ben Hassine (1977) accepted *C. mugilis* as a different species from *Chelon labrosus* (Risso, 1827) and described it from only female specimens. They also compared females of *C. mugilis* from *C. labrosus* and *C. minimus* from *Dicentrarchus labrax* (Linnaeus, 1758) in Tunisia. The female of the new species differs from *C. mugilis* in having a smaller body at 3.79 mm (5.33 mm in *C. mugilis*); a genital complex which is about 1.6 times longer than the abdomen (3.2 times in *C. mugilis*); an abdomen with two indistinct somites (one somite in *C. mugilis*); tines of sternal furca little divergent, slightly elongated (divergent, short tines in *C. mugilis*); number of teeth on mandible as 13 (12 in *C. mugilis*); posterolateral corners of genital complex indistinctly lobate not extending to middle or anterior of the abdomen (distinctly lobate, extending slightly beyond the middle of abdomen in *C. mugilis*); ratio of length/anterior margin of maxillule endopodite is 1.45 (1.1 in *C. mugilis*); myxal surface of maxilliped with a slight process (absent in *C. mugilis*); and ratio of first spine/third spine on fourth leg is 3.2 (3.4 in *C. mugilis*). The male of the new species could not be compared as the male of *C. mugilis* was not described. The other species reported from *M. cephalus* is *Caligus minimus* which was described on *D. labrax* by Otto (1821). The female of the new species differs from *C. minimus* in having a smaller body 3.79 mm in comparison with 4.38 mm in *C. minimus*; genital complex is about 1.6 times longer than abdomen (2.3 times in *C. minimus*); abdomen with indistinctly two somites (one somite in *C. minimus*); tines of sternal furca are little divergent, slightly elongated (slightly divergent short in *C. minimus*) (Fig. 6d); number of teeth on mandible is 13 (12 teeth in *C. minimus*) (Fig. 6m); posterolateral corners of genital complex indistinctly lobate not extending to middle or anterior of the abdomen (distinctly lobate,

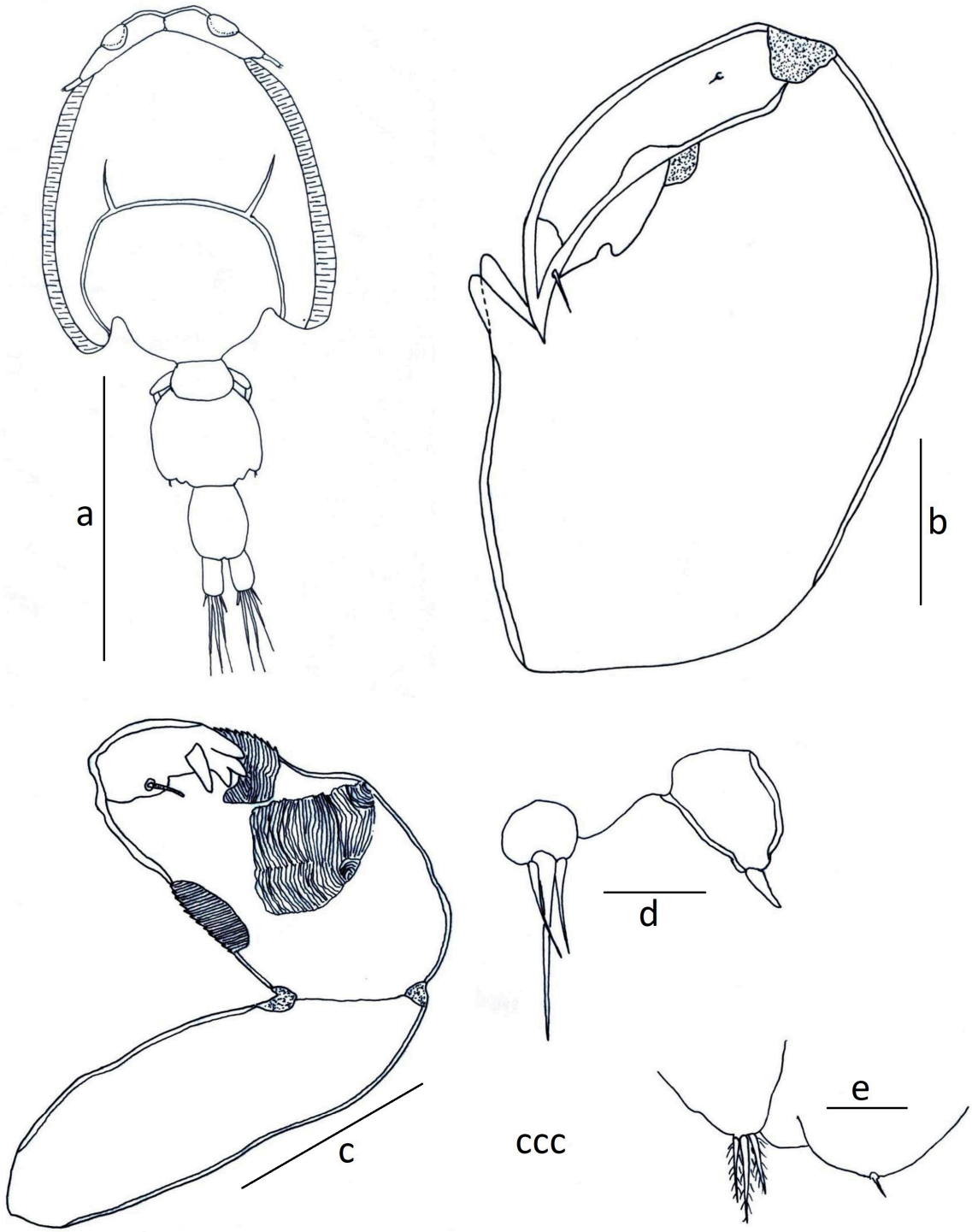

Fig. 5. *Caligus turkiyensis* n. sp. **a:** Male (1.74 mm); **b:** Maxilliped (0.18 mm); **c:** Antenna (0.16 mm); **d:** Maxillule (0.03 mm); **e:** Fifth leg (0.03 mm)

Species	Leg 1 (exopod/ endopod)	Leg 2 (exopod/ endopod)	Leg 3(exopod/ endopod)	Leg 4 (exopod/ endopod)
C. turkiyensis n. sp	I-0; III, 1, 3/ vesitigial	I-1; I-1; II, I, 5/ 1-0; 2-0; 6	I,0; I-1; III, 4/ 1-0; 6	I-0; III/ Absent
C. apodus	I-0; III, I, 3/ vestigial	I-1; I-1; II, 1, 5/ 0-1; 0-2; 6	I-0; I-1; III, 4/ 0-1; 6	Absent
C. pageti	I-0; III, 1, 3/ vestigial	I,1; I,1: II, I, 5/ 1,0; 2,0; 6	I,0; I-1; III,4/ 1-0; 6-0	I-0; II/ Absent

Table II. Setal and spinal formula of legs 1-4 of *Caligus* species found in this study.

extend slightly beyond one third of abdomen in *C. minimus*); terminal segment of antenna and postantennal process slightly recurved (strongly recurved in *C. minimus*) (Fig. 6f, h); ratio of length/anterior margin of maxillule endopo

Male of the new species differs from *C. minimus* in having a smaller body 3.67 mm (4-5 mm in *C. minimus*); myxal surface of maxilliped with one small process in distal and one large bifid process in proximal (one large process in proximal of *C. minimus*) (Fig. 6j); terminal segment of antenna with quadrifid plate and a basal seta (quadrifid plate in *C. minimus*).

Caligus curtus was described from *Merlangius merlangus* (Linnaeus, 1758) in Denmark and Norway waters by Müller (1785). It can be distinguished from *C. turkiyensis* n. sp. in having: a greater body, 8.7 mm in comparison to 3.79 mm; a genital complex about 2.5 times longer than the abdomen (1.6 times in *C. turkiyensis* n. sp.); an abdomen with one somite (indistinctly two somites *in C. turkiyensis* n. sp.); tines of sternal furca slightly divergent, short parallel (little divergent, slightly elongated in *C. turkiyensis* n. sp.); number of teeth on mandible 12 (13 teeth in *C. turkiyensis* n. sp.); posterolateral corners of genital complex distinctly lobate, extend slightly beyond one third of abdomen (indistinctly lobate not extending to middle or anterior of the abdomen in *C. turkiyensis* n. sp.); terminal segment of antenna and postantennal process strongly recurved (slightly recurved in *C. turkiyensis* n. sp.); ratio of length/anterior margin of maxillule endopodite of 0.8 (1.45 in *C. turkiyensis* n. sp.); and ratio of first spine/third spine on fourth leg of 5 (3.2 in *C. turkiyensis* n. sp.). Male of *C. curtus* differs from *C. turkiyensis* n. sp. in having a greater body of 7.93 mm in comparison to 3.67 mm in *C. turkiyensis* n. sp.; myxal surface of maxilliped with one large process in both proximal and distal (one small process in distal and one large bifid process in proximal of *C. turkiyensis* n. sp.); and terminal segment of antenna with bifid plate and a basal seta (quadrafid plate and a basal seta in *C. turkiyensis* n. sp.) and denticles on first spine of fourth leg present (absent in *C. turkiyensis* n. sp.).

Caligus dicentrarchi was found on *D. labrax* farmed in Corsica and Sete by Cabral & Raibaut, 1986. The female of the new species can be differentiated from *C. dicentrarchi* in having: a smaller body of 3.79 mm in comparison to 6.2 mm in *C. dicentrarchi*; genital complex is about 1.6 times longer than the abdomen (2.6 times in *C. dicentrarchi*); abdomen with indistinctly two somites (one somite in *C. dicentrarchi*); tines of sternal furca little divergent, slightly elongated (short parallel in *C. dicentrarchi*); number of teeth on mandible 13 (12 teeth in *C. dicentrarchi*); posterolateral corners of genital complex indistinctly lobate not extending to middle or anterior of the abdomen (distinctly lobate, extend slightly beyond one-third of abdomen in *C. dicentrarchi*); ratio of length/anterior margin of maxillule endopodite of 1.45 (1.2 in *C. dicentrarchi*); myxal surface of maxilliped with a slight process (absent in *C. dicentrarchi*); and ratio of first spine/third spine on fourth leg of 3.2 (4.5 in *C. dicentrarchi*). Male of the new species differs from *C. dicentrarchi* in having a smaller body of 3.67 mm (6.5 mm in *C. dicentrarchi*); myxal surface of maxilliped with one small process in distal and one large bifid process in proximal (one large process in proximal of *C. dicentrarchi*); terminal segment of antenna with quadrifid plate and a basal seta (trifid plate in *C. dicentrarchi*). Boxshall (2018) classified some *Caligus* species in 5 groups according to a combination of several morphological characters, such as leg 1, 2 and 4, antenna, maxilla, and abdomen of female. These groups are *Caligus bonito*-group, *Caligus confusus*-group, *Caligus diaphanus*-group, *Caligus macarovi*-group, and *Caligus productus*-group. The number of these groups reached 7 with the revision of *Caligus pseudorhombi*-group and

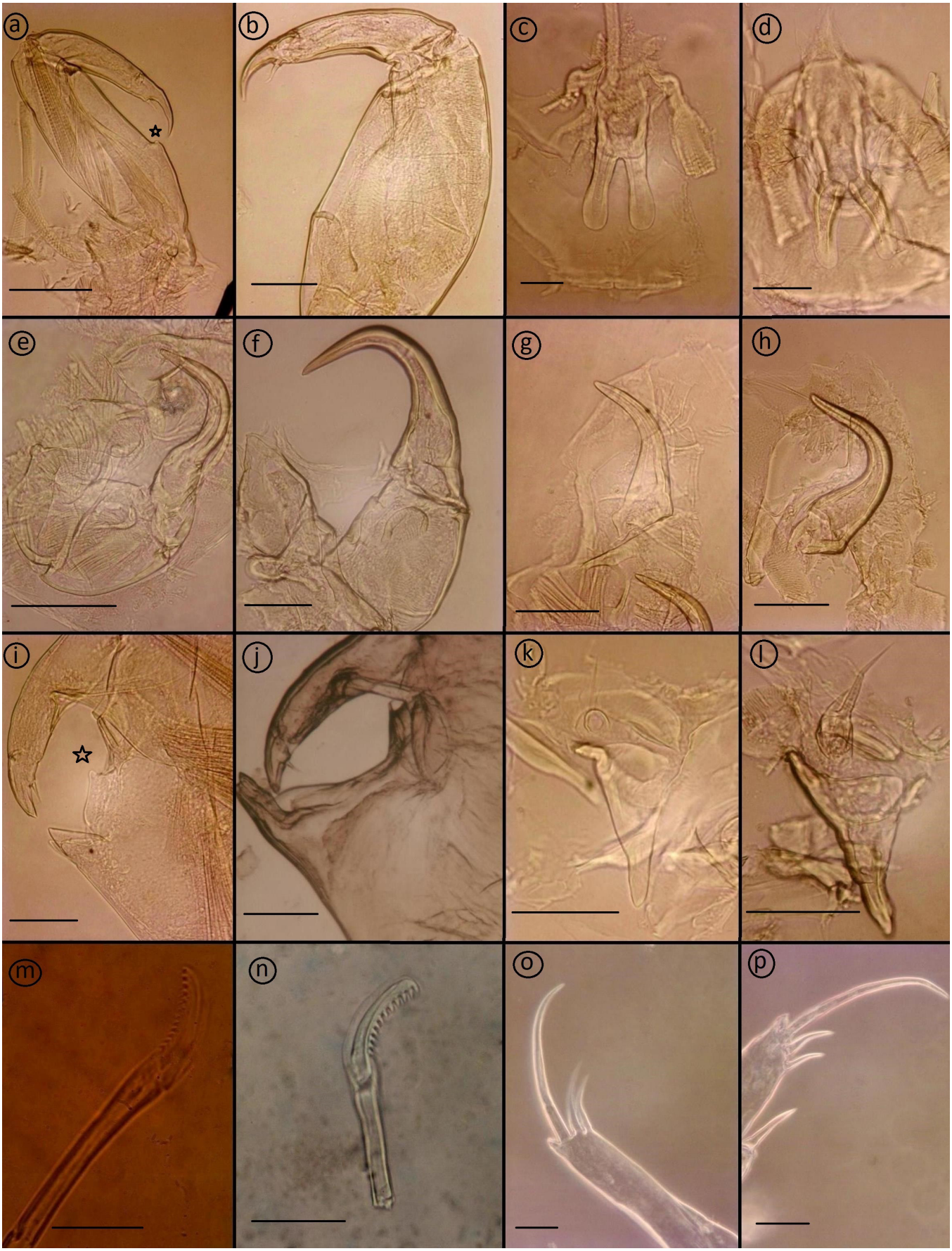

Fig. 6. *Caligus turkiyensis* n. sp female, **a:** Maxilliped (0.11 mm); **c:** Sternal furca (0.04 mm); **e:** Antenna (0.16 mm); **g:** Postantennal process (0.10 mm); **k:** Maxillule (0.08 mm); **m:** Mandible (0.04 mm); **o:** Fourth leg (0.05 mm); male, **i:** Maxilliped (0.07 mm); *Caligus minimus*, female **b:** Maxilliped (0.14 mm); **d:** Sternal furca (0.06 mm); **f:** Antenna (0.07 mm); **h:** Postantennal process (0.09 mm); **l:** Maxillule (0.09 mm); **m:** Mandible (0.05 mm); **p:** Fourth leg (0.05 mm); male, **j:** Maxilliped (0.07 mm).

Caligus undulatus-group by Ohtsuka & Boxshall (2019) and Ohtsuka *et al*. (2020), respectively. *Caligus turkiyensis* n.sp. may also be closely related to the *C. macarovi*-group. First and second exopodal segments of 3-segmented leg 4 with I and III spines in this group are the same in the new species. The proximal segment of female antenna has a posterior process, as in this group. The new species differs from the *C. macarovi*-group: female abdomen is 2-segmented indistinctly in the new species, but group carries 1-segmented. Distal of maxilla brachium in this group has marginal serrations, but is absent in the new species. Structure of setal and spinal of leg 1 in new species is similar to the rest group. This species has also the distal exopodal segment of leg 1 bears 3 plumose setae and 4 distal elements. Spines 1-3 are all subequal in length and seta 4 is markedly longer than spines in this group. Spine 1 (outermost) and seta 4 are smooth and longer than spines 2-3; spines 2 and 3 are about equal in length in new species. Only spines 2 and 3 carry accessory processes in this group, but spines 2 and 3 both lack accessory process and arcuated with blunt ends. Many morphological characters of the new species are different from the *C. macarovi*-group. Therefore, it is likely that it does not belong to this group.

DISCUSSION

Caligus apodus, *C. mugilis* and *C. pageti* have been reported mostly from countries along the Mediterranean coast, except for one report from the Atlantic Ocean (Angola) for *C. apodus* and from Ireland and South Africa for *C. pageti* (Fig. 7). Considering the geographical distribution of these parasites, this distribution suggests they are mostly specific to the Mediterranean.

The Sea of Marmara, where the new species discovered in this study was found, is a transitional area between the Black Sea and the Mediterranean, and is under the influence of both these seas. The Sea of Marmara has unique hydrographic, hydrological and oceanographic features. In addition, there is a dense human population around the Sea of Marmara and Bandırma Bay, which are then affected by both domestic and industrial pollution (Öztürk 2021). Due to the unique environmental characteristics of the Sea of Marmara, speciation may have occurred in *Caligus* parasites in link geographical isolation.

Caligus apodus, *C. mugilis* and *C. pageti* have high host specificity and have been reported mostly from 5 species of mugilids: *Mugil cephalus*, *Chelon auratus*, *C. labrosus*, *C. ramada* (Risso, 1827) and *C. saliens* (Risso, 1810). In addition, *C. apodus* has been reported from *Crenimugil crenilabis* (Forsskål, 1775), *Planiliza carinata* (Valenciennes, 1836), and *Crenimugil seheli* (Fabricius, 1775) in Israel by Paperna & Overstreet (1981) (Table III).

Apart from mullets, *C. apodus* was reported from different hosts, such as the common sole, *Solea solea* (Linnaeus, 1758) from Iskenderun Bay, Turkey by Özak *et al*. (2013). The reason why this parasite has been reported from the common sole as well as mullets is probably because the habitats of these hosts are similar. Common sole live in demersal habitats, while *C. labrosus* and *C. saliens* live in demersal, *M. cephalus* in benthopelagic and *C. auratus* and *C. ramada* in pelagic-neritic habitats (Froese & Pauly 2024). Apart from pelagic-neritic, the presence of these fish in similar habitats increases the possibility of parasites changing hosts between mullets and common sole.

Venmathi Maran *et al*. (2016) reviewed the presence and explaining factors of caligid copepods in coastal and marine plankton. Caligids may be found in plankton, because they escape from their host, host switch or search for a new host, change of mode of life, and accidental detachment from the host. This behavior supports the possibility to be found on different hosts.

Due to their host specificity, Boualleg *et al*. (2011) and Ben Mansour & Ben

Hassine (1998) defined *C. mugilis* and *C. pageti* as stenoxenous species, respectively. Ragias *et al*. (2004) only reported it from sea bass, for the same reasons as above.

Caligus minimus has been mainly reported from the North Atlantic Ocean, Mediterranean, Adriatic, Sea of Marmara and Black Sea (Radujkovic & Raibaut 1989, Özak 2020). In addition, there are reports of *C. minimus* from perciforms other than sea bass, such as Alosidae, Moronidae, Gadidae, Labridae, Mugilidae, Sparidae, Percidae, and Sciaenidae.

The geographical distribution of *C. curtus* includes the Arctic-Boreal region of the Atlantic Ocean and contiguous waters. It is mainly a typical parasite of marine gadids, but has been reported from marine fish from various families, including elasmobranchs (see Parker *et al*. 1968). Considering the host specificity of *C. curtus* and *C. minimus*, they may be defined as euryxenous parasite species.

The number of studies on species of *Caligus* in the Mediterranean and Aegean coasts of Turkey is higher than in the Marmara Sea and Black Sea. Twenty of *Caligus* have been recorded hitherto from Turkish Coasts, of which 19 are from Mediterranean and Aegean Coasts, 5 from Sea of Marmara and 1 from Black Sea Sea (Özak 2020). This parasitological study still includes species of *Caligus* of mullets in a limited region. The discovery of *Caligus turkiyensis* n.sp. increases the 21st species of *Caligus* for Turkish fauna.

Information about the host specificity, host-parasite relationship and zoogeography of parasites of mullets is very important from zoological and ecological point of view. Parasites cause mass and serious fish deaths (Paperna & Lahav 1974). Infections by monoxenous parasites such as monogenea, parasitic crustaceans are more effective in farmed fish (Bragoni *et al*. 1984, Paperna 1987, Stella *et al*. 2023). Mullet is the close contact of with farmed fish, which can transmit pathogens such as parasites, viruses, bacteria, etc. to these fish and cause infection, leading to serious economic losses (Johnson *et al*. 2004, Paladini *et al*. 2017, Assane *et al*. 2022). It is also important to identify parasites for fish farming to take precautions against possible infections in the future

CONCLUSION

Although *Caligus apodus* and *C. pageti* were known as specific to the coasts of the Mediterranean Sea and Aegean Sea, there are uncertainties about the morphological characters and geographic distribution of the caligids in the Sea of Marmara. This study presented *C. apodus*, *C. pageti* and the morphological characters of a new species *Caligus turkiyensis* n. sp. from the sea of Marmara. Although morphological characters of this new species are described in this study, molecular studies are needed to confirm its species status.

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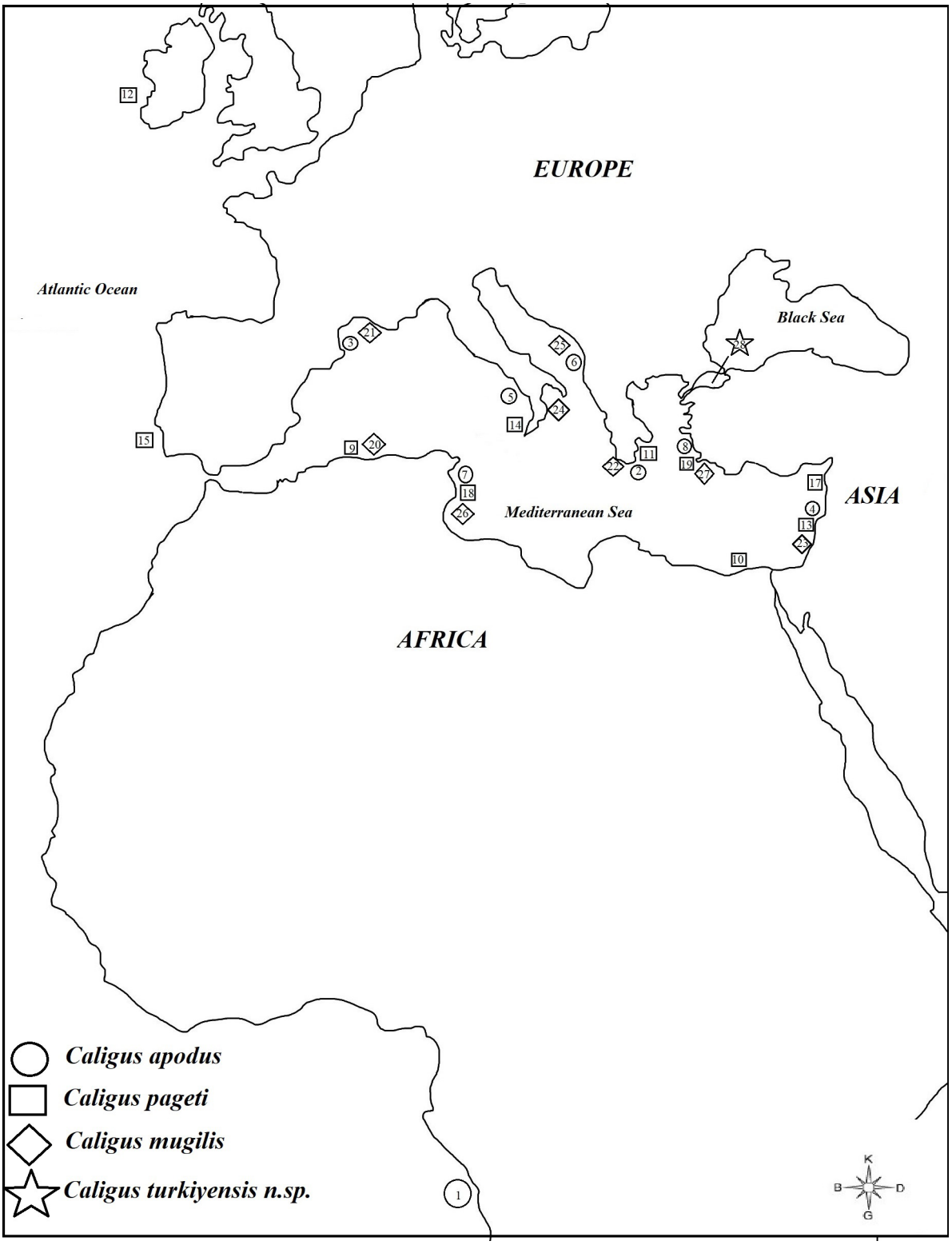

Fig. 7. *Caligus apodus*: **1:** Angola (Capart 1959), **2:** Grece (Ragias *et al*. 2004), **3:** France (Braun 1981), **4:** Israel (Paperna & Overstreet 1981), **5:** Italy (Merella & Garippa 2001), **6:** Montenegro (Radujkovic & Raibaut 1987), **7:** Tunisia (Raibaut & Ben Hassine 1977), **8:** Turkey (Altunel 1983), *Caligus pageti*: **9:** Algeria (Brian 1931), **10:** Egypt (Russell 1925), **11:** Greece (Ragias *et al*. 2004), **12:** Ireland (Holmes 1998), **13:** Israel (Paperna 1975), **14:** Italy (Merella & Garippa 2001), **15:** Portugal (Santos 1996), **16:** South Africa (Oldewage & van As 1989), **17:** Syria (Hassan *et al*. 2022), **18:** Tunisia (Raibaut & Ben Hassine 1977), **19:** Turkey (Altunel 1983), *Caligus mugilis*: **20:** Algeria (Boualleg *et al*. 2010), **21:** France (Braun 1981), **22:** Greece (Ragias *et al*. 2004), **23:** Israel (Paperna & Overstreet 1981), **24:** Italy (Brian 1906), **25:** Montenegro (Radujkovic & Raibaut 1987), **26:** Tunisia (Raibaut & Ben Hassine 1977), **27:** Turkey (Ben Hassine 1983), *Caligus turkiyensis* n. sp. **28:** Turkey (in the present study).

Table III. - Hosts and localities of *Caligus* species reported in Mediterranean.

Caligid Species	Host	Locality	References
Caligus apodus	*Chelon labrosus*	France, Italy, Montenegro, Tunisia, Turkey	Raibaut & Ben Hassine (1977), Altunel (1983), Radujkovic & Raibaut (1987), Merella & Garippa (2001), Braun (1981)
	Chelon auratus	Israel, Tunisia, Turkey	Raibaut & Ben Hassine (1977), Paperna & Overstreet (1981), present study
	Chelon ramada	France, Israel, Italy, Tunisia, Turkey	Raibaut & Ben Hassine (1977), Altunel (1983), Merella & Garippa (2001), Paperna & Overstreet (1981), Braun (1981)
	Chelon saliens	France, Israel, Italy, Montenegro, Tunisia, Turkey	Raibaut & Ben Hassine (1977), Altunel (1983), Radujkovic & Raibaut (1987), Merella & Garippa (2001), Paperna & Overstreet (1981), Braun (1981)
	Mugil cephalus	Angola, France, Israel, Italy, Tunisia, Turkey	Capart (1959), Raibaut & Ben Hassine (1977), Altunel (1983), Merella & Garippa (2001), Paperna & Overstreet (1981), Braun (1981)
	Oedalechilus labeo	Montenegro	Radujkovic & Raibaut (1987)
	Crenimugil crenilabis	Israel	Paperna & Overstreet (1981)
	Planiliza carinata	Israel	Paperna & Overstreet (1981)
	Crenimugil seheli	Israel	Paperna & Overstreet (1981)
	Dicentrarchus labrax	Greece	Ragias *et al.* (2004)
	Solea solea	Turkey	Özak *et al*. (2013)
Caligus pageti	*Chelon labrosus*	Ireland, Israel, Tunisia, Turkey	Paperna (1975), Raibaut & Ben Hassine (1977), Altunel (1983), Holmes (1998)
	Chelon auratus	Algeria, Israel, Italy, South Africa, Tunisia	Brian (1931) cited by Ramdane & Trilles (2007), Raibaut *et al*. (1971), Oldewage & van As (1989), Merella & Garippa (2001), Dzikowski *et al*. (2003)
	Chelon saliens	Algeria, Italy, Tunisia, Turkey	Raibaut *et al*. (1971), Altunel (1983), Merella & Garippa (2001), Boualleg *et al*. (2010)
	Mugil cephalus	Israel, South Africa, Syria, Tunisia, Turkey	Raibaut & Ben Hassine (1977), Paperna & Lahav (1974), Altunel (1983), Hassan *et al*. (2022), present study
	Chelon ramada	Egypt, Israel, South Africa, Tunisia, Turkey	Russell (1925), Paperna (1975), Raibaut & Ben Hassine (1977), Altunel (1983), Oldewage & van As (1989)
	Dicentrarchus labrax	Portugal, Greece	Santos (1996), Ragias *et al*. (2004)
Caligus mugilis	*Mugil cephalus*	Algeria, Italy	Brian (1906), Boualleg *et al*. (2010)
	Chelon labrosus	Algeria, France, Israel, Italy, Montenegro, Tunisia, Turkey	Boualleg *et al*. (2010), Merella & Garippa (2001), Raibaut & Ben Hassine (1977), Paperna & Overstreet (1981), Ben Hassine (1983), Braun (1981), Radujkovic & Raibaut (1987)
	Chelon auratus	Algeria	Boualleg *et al*. (2010)
	Chelon ramada	Algeria	Boualleg *et al*. (2010)
	Dicentrarchus labrax	Greece	Ragias *et al*. (2004)
Caligus turkiyensis n. sp.	*Mugil cephalus*	Turkey	present study

Caligus Species	*Caligus turkiyensis* n. sp.	*Caligus mugilis*[1]	*Caligus minimus*[2]	*Caligus curtus*[3]	*Caligus dicentrarchi*[4]
Female					
Length of total body	3.79 mm (3.13-4.61)	5.33 mm (5.26- 5.4)	4.38 mm (4.36-4.40)	8.7 mm (5.1-10.1)	6.2 mm
Genital complex length/ Abdomen length	1.6: 1	3.2: 1	2.3: 1	2.5: 1	2.6: 1
Number of segment in abdomen	2 (indistinctly)	1	1	1	1
Length of tines in the sternal furca	Little divergent, slightly elongated	slightly divergent short	Slightly divergent short	Slightly divergent, short parallel	Short parallel
Number of teeth on mandible	13 teeth	12 teeth	12 teeth	12 teeth	12 teeth
Posterolateral corners of genital complex	Indistinctly lobate, not extend to anterior of the abdomen	Distinctly lobate, extend slightly beyond the middle of abdomen	Distinctly lobate, extend slightly beyond one third of abdomen	Distinctly lobate, extend slightly beyond one third of abdomen	Distinctly lobate, extend slightly beyond one third of abdomen
Terminal claw of antenna	Slightly recurved	Slightly recurved	Strongly recurved	Strongly recurved	Slightly recurved
Postantennal process	Slightly recurved	Slightly recurved	Strongly recurved	Strongly recurved	Slightly recurved
Length/ Anterior margin of maxillule endopodite	1.45 times	1.1 times	1.6 times	0.8 times	1.2 times
Process on myxal surface of maxilliped	A slight process	Absent	Absent	A slight process	Absent
First spine/ Third spine on fourth leg	3.2 times	3.4 times	5 times	5 times	4.5 times
Denticles on first spine of fourth leg	Absent	Unknown	Absent	Present	Absent
Male					
Length of total body	3.67 mm (3.30-4.69)	Unknown	4-5mm	7.93 mm (5.38-12.3)	6.5 mm
Process on myxal surface of maxilliped	One small process in distal and one large bifid process in proximal	Unknown	One large process in proximal	One large process in both proximal and distal	One large process in proximal
Terminal segment of antenna	Quadrafid plate and a basal seta	Unknown	Quadrafid plate	Bifid plate and a basal seta	Trifid plate

[1]From Raibaut & Ben Hassine (1977); [2]From Raibaut & Ben Hassine (1977) and Kabata (1979); [3]From Parker *et al.* (1968); [4]From Cabral & Raibaut (1986)

Table IV.- Some morphological characters distinguishing *Caligus turkiyensis* n.sp. from congeneric species

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