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Siphonostomatoida: Caligidae) from  
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# *Pseudanuretes anfoozi* n. sp. (Copepoda: Siphonostomatoida: Caligidae) from the yellowbar angelfish *Pomacanthus maculosus* (Forsskål) in coral reefs off Iraq

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**Abstract** A new species of *Pseudanuretes* Yamaguti, 1936 (Copepoda: Caligidae) parasitic on the gills of the yellowbar angelfish *Pomacanthus maculosus* (Forsskål) from a coral reef off Iraq, north-western Arabian Gulf, is described. *Pseudanuretes anfoozi* n. sp. belongs within a group of species characterised by the spear-like structure of leg 4. Morphologically *P. anfoozi* n. sp. is similar to *P. papernai* Kabata & Deets, 1988 in possessing an armature of I,6 on the third exopodal segment of leg 2 rather than I,7 in the other species of this group. However, *P. anfoozi* n. sp. can be distinguished from *P. papernai* by the possession of only 5 caudal setae instead of 6, and in the shape of the caudal rami, which are shorter and wider in new species. In addition, these two species differ in the shape of the genital complex of the adult female.

## Introduction

Coral reefs are areas of great biodiversity (Reaka-Kudla, 1997; Patrick et al., 2014). The unique Iraqi coral reef was only recently discovered and comprises 28 km<sup>2</sup> of coral-bearing aquatic environment in a turbid coastal area where the temperature of the sea water fluctuates between 14–34°C (Pohl et al., 2014). Currently this unusual habitat is known to harbour 93 species of marine fishes representing 48 families, compared with 322 marine fishes in the whole of Iraqi waters (Ali et al., 2018). The family Pomacanthidae is represented by three species of the genus *Pomacanthus* Lacepède (Jawad et al., 2018). The yellowbar angelfish *Pomacanthus maculosus* (Forsskål) has a large yellow vertical blotch on the side of the adult, whereas juveniles are black with many light blue and white vertical stripes on the side. This species is considered one of the ornamental fishes occurring in coral reef habitat that are in urgent need of attention for the conservation project in Iraq (Jawad et al., 2014). It is distributed in the western Indian Ocean, Red Sea, Gulf of Oman and the Arabian Gulf, most often in areas around coral and rocky reefs but occasionally in sandy areas (Froese & Pauly, 2019).

The family Caligidae Burmeister, 1835, with currently 30 genera listed as valid in WoRMS database (WoRMS, 2019), is represented in Iraq by 13 species belonging to four genera: *Anuretes* Heller, 1865 (3 species); *Caligus* Müller O. F., 1785 (6 species);

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This article belongs to the Topical Collection Arthropoda.

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*Hermilius* Heller, 1865 (3 species); and *Mappates* Rangnekar, 1958 (1 species) (see Mhaisen et al., 2018). The genus *Pseudanuretes* Yamaguti, 1936 includes nine valid species (Walter & Boxshall, 2019) typically found on species of reef-associated fish families, including the Chaetodontidae, Ehippididae and Pomacanthidae (Yamaguti, 1936, 1963).

Marine pomacanthids are important commercially and as aquarium fishes, but there is a lack of parasitological investigations on this fish in Iraq, with the exception of Li et al. (2016) who focused on helminths. This study is the first report on copepods parasitic on *P. maculosus* and describes a new species of *Pseudanuretes*.

## Materials and methods

A total of 35 parasitic copepods were collected from 10 individuals of *P. maculosus* (total length of 185–310 mm) caught at the Iraqi coral reef in the Arabian Gulf (29°25'N, 48°48'E), during the period from November 2017 to January–February 2018. In the laboratory, the gill chambers were examined under a dissection microscope (Optika S2-ST1). The copepods were isolated from inner gill chambers and gill filaments and preserved in 70% ethanol, before being mounted in 80% lactic acid on glass slides [see Khamees & Adday (2013) for the modified procedure replacing the wooden slide method of Humes & Gooding (1964)]. Measurements are presented in micrometres unless otherwise indicated, as the range followed by the mean in parentheses. All drawings were prepared with the aid of drawing tube on an Olympus C X 21 FS1 compound microscope.

### Family Caligidae Burmeister, 1835

#### Genus *Pseudanuretes* Yamaguti, 1936

#### *Pseudanuretes anfoozi* n. sp.

*Type-host*: *Pomacanthus maculosus* (Forsskål) (Perciformes: Pomacanthidae), yellowbar angelfish.

*Type-locality*: Iraqi coral reef in the Arabian Gulf (29°25'N, 48°48'E), north-western Arabian Gulf, Iraq.

*Type-material*: Holotype, adult female (NHMUK 2019.1059), coll. xi.2017; paratypes, 7 adult females

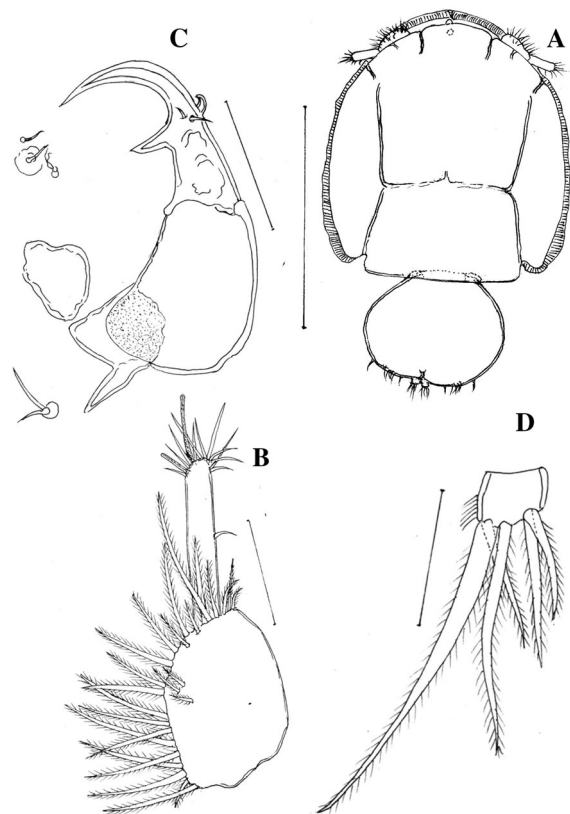
(NHMUK 2019.1060–1066), coll. Atheer H. Ali. Material examined: 10 female copepods (6 ovigerous and 4 non ovigerous) and 1 male.

*Site in host*: Inner gill operculum, gill filaments.

*Prevalence and mean intensity*: 81.8% (9 infected fish hosts from 11 examined fish); 11 parasites per infected fish (range 1–33).

*ZooBank registration*: To comply with the regulations set out in Article 8.5 of the amended 2012 version of the *International Code of Zoological Nomenclature* (ICZN, 2012), details of the new species have been submitted to ZooBank. The Life Science Identifier (LSID) for *Pseudanuretes anfoozi* n. sp. is urn:lsid:zoobank.org:act: F2FD840C-A86C-4E32-911E-6B7C86DD84CF.

*Etymology*: The specific name, *anfoozi*, is derived from the local name of the type-host, *Pomacanthus maculosus*, in Iraq.



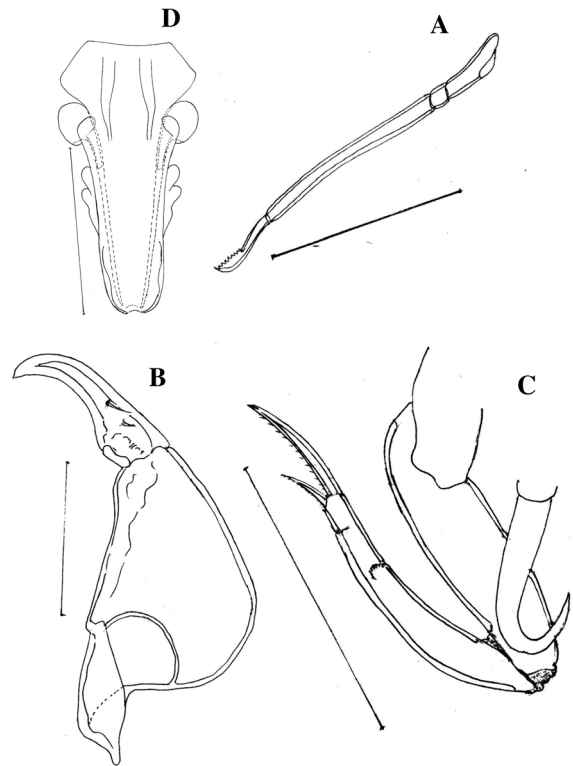
**Fig. 1** *Pseudanuretes anfoozi* n. sp. Adult female. A, Habitus, dorsal; B, Antennule; C, Antenna and maxillule; D, Caudal ramus. Scale-bars: A, 100  $\mu$ m; B–D, 50  $\mu$ m

Description

*Female* [Based on 10 specimens.] Body (Fig. 1A) 1.02–1.24 (1.10) mm in length (excluding caudal setae). Dorsal cephalothoracic shield with narrow marginal membrane laterally; cephalic zone comprising more than half of cephalothorax (Fig. 1A); thoracic zone sub-quadrangular, truncate posteriorly 700–870 × 630–740 (770 × 640) (excluding marginal hyaline membrane); about 1.14 times longer than wide in holotype. Fourth pedigerous somite hidden under cephalothoracic shield in dorsal view in most examined specimens (Fig. 1A); wider than long, width 410–450 (430). Genital complex (Fig. 1A) oval in shape, overlapped by rear margin of cephalothorax, slightly wider than long 310–410 × 340–420 (350 × 390) with posteromedial cleft. Abdomen not expressed, fully incorporated into rear of genital complex. Caudal ramus (Fig. 1D) minute, wider than long, 12–17 × 16–22 (14.6 × 19), armed with 5 setae (1 long, 1 medium and 3 short), longest seta about 1.5 times longer than medium seta. Egg-sac short 230–290 (267).

Antennule (Fig. 1B) 2-segmented; proximal segment robust, 80–120 (103) armed with 22 setae and 3 simple setae; distal segment slender with 11 setae plus 2 aesthetascs and single seta on middle posterior margin. Antenna (Fig. 1C) 3-segmented; basal segment small, bearing pointed spinous process; middle segment subrectangular, unarmed; distal segment tipped with strongly curved, acutely pointed claw, armed with acute secondary tine proximally and with 2 setae. Postantennal process (Fig. 1C) represented by 3 sensillate papillae, with 1, 1 and 2 sensilla.

Mouth tube (Fig. 2D) slender, with interbuccal stylet on labrum and strigil on labium. Mandible (Fig. 2A) consisting of 4 sections, distal end blade-like with 12 marginal teeth. Maxillule (Fig. 1C) reduced to small papilla bearing 2 unequal setae; posterior process absent. Maxilla (Fig. 2C) 2-segmented, proximal segment (lacertus) sub-cylindrical and unarmed; distal segment (brachium) slender, carrying naked, subterminal cana and bilaterally pinnate terminal calamus. Maxillary whip of medium length (Fig. 2C). Maxilliped (Fig. 2B) with robust unarmed corpus; subchela relatively short, tipped with claw with pair of short setae. Sternal furca absent. Armature of rami of legs 1–4 as follows (Roman numerals indicating spines and Arabic numerals setae):

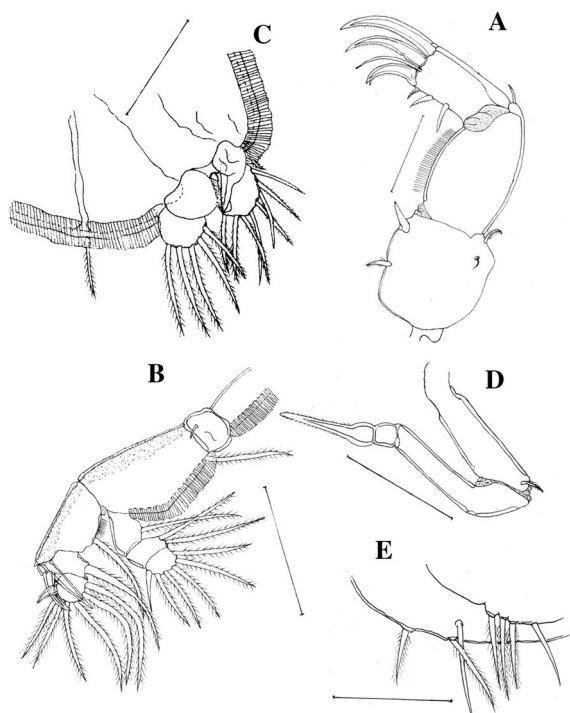


**Fig. 2** *Pseudanuretes anfoozi* n. sp. Adult female. A, Mandible; B, Maxilliped; C, Maxilla and maxillary whip; D, Mouth tube Scale-bars: A, 100 μm; B–D, 50 μm

	Exopod	Endopod
Leg 1	I-0; III, 1, 3	vestigial
Leg 2	I-1; I-1; I, 6	0-1; 0-2; 6
Leg 3	I-0; III, 5	5
Leg 4	I	absent

Leg 1 (Fig. 3A) sympod, subquadrangular bearing outer pinnate seta near anterior margin and single sensillum, plus inner pinnate seta derived from basis; endopod naked vestigial, acuminate; exopod 2-segmented, first segment with row of setules and spini-form outer seta; second segment with 4 distal elements, inner element (spine 3) with accessory process (Fig. 3A), seta 4 displaced onto surface of segment.

Leg 2 (Fig. 3B) biramous, coxa small with sensilla and large plumose seta on posterior margin; first exopodal segment large, with outer spine extending



**Fig. 3** *Pseudanuretes anfoozi* n. sp. Adult female. A, Leg 1; B, Leg 2; C, Leg 3; D, Leg 4; E, Legs 5 and 6. Scale-bars: 50  $\mu$ m

just beyond apical margin of third segment; basis and first exopodal segment each provided with flap of marginal membrane reflexed back over dorsal surface.

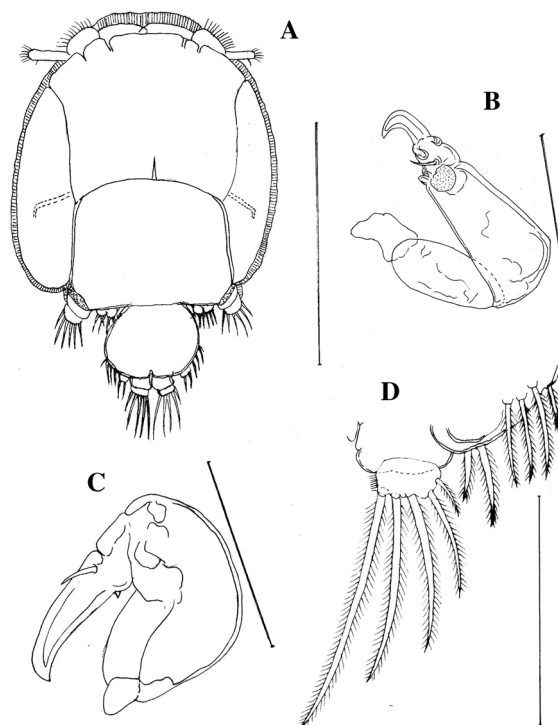
Leg 3 (Fig. 3C) protopod (apron) with small, plumose, outer seta derived from basis and inner plumose seta derived from coxa; broad hyaline membrane present along lateral margin, posterior margin fringed with setules.

Leg 4 (Fig. 3D) reduced, protopod with outer pinnate seta near articulation with second segment; exopod 2-segmented, proximal segment long, terminal segment with bilaterally pinnate spiniform element.

Leg 5 (Fig. 3E) represented by small ridge on genital complex bearing with 3 pinnate setae and 1 naked seta.

Leg 6 (Fig. 3E) represented by pinnate seta and 2 naked setae on posterolateral margin of genital complex.

**Male** [Based on a single specimen; Fig. 4]. Body (Fig. 4A) small, 800 long (excluding setae on caudal rami). Cephalothoracic shield as in female, just longer than wide, 600  $\times$  550. Fourth pediger distinctly wider than long, 20  $\times$  120. Genital complex wider than long, 150  $\times$  200, possessing legs 5 and 6 ventrally at posterolateral corner (Fig. 4D). Abdomen (Fig. 4A) short and wide, 23  $\times$  83. Caudal ramus (Fig. 4D)



**Fig. 4** *Pseudanuretes anfoozi* n. sp. Male. A, Habitus, dorsal; B, Antenna; C, Maxilliped; D, Right side of posterior part of the genital complex. Scale-bars: A–C, 50  $\mu$ m; D, 100  $\mu$ m

wider than long, 20  $\times$  30, armed with 1 small and 4 longer plumose setae, gradually decreasing in length from inner- to outermost.

Antenna (Fig. 4B) 3-segmented; proximal segment small, rectangular and unarmed; middle segment largest, with 3 small adhesion pads located on medial surface; distal segment forming recurved claw, with 2 plates plus 1 seta in basal region. Maxilliped (Fig. 4C) with basal segment robust, about as long as subchela; subchela bearing 2 spiniform setae proximally, near base of claw.

Leg 5 (Fig. 4D) represented by 1 short and 3 long pinnate setae on posterolateral margin of genital complex. Leg 6 (Fig. 4D) represented by posterolateral lobe tipped with 2 long pinnate setae posterior to leg 5.

## Discussion

Yamaguti (1936) established the genus *Pseudanuretes* to accommodate the type-species *P. chaetodontis* Yamaguti, 1936 based on the presence of an accessory

claw located proximally on the distal segment of the antenna (Yamaguti, 1963). The validity of *Pseudanuretes* has been questioned (see Dojiri & Ho, 2013) but Kabata (1965) concluded the genus was valid and Kabata (1965) inferred that the differences in the morphology of the fourth leg between congeneric species should be interpreted as a progressive reduction within the genus.

Rangnekar (1957) subsequently described *P. schmitti* Rangnekar, 1957 from *Platax teira* (Forskål). Kabata (1965) described *P. fortipedis* Kabata, 1965 from *Chaetodontoplus conspicillatus* (Waite) and considered *P. schmitti* to be questionable because the original description utilised characters that he regarded as unsuitable and invalid for generic level discrimination. Kabata (1965) considered removing *P. schmitti* from *Pseudanuretes*, but Dojiri & Ho (2013) retained it, stating that the type-specimens needed to be re-examined before any conclusions on the generic placement of this species can be reached. Prabha & Pillai (1983) added *P. pomacanthodi* Prabha & Pillai, 1983 from *Pomacanthus imperator* (Bloch) and highlighted that leg 4 displays the main characters for distinguishing the genus. Pillai (1985) prepared a key to the four species found in India, including the questionable *P. schmitti*. A second species of *Pseudanuretes* (*P. indicus*) from the same host, *P. imperator*, was described by Prabha & Pillai (1986).

Kabata & Deets (1988) described *P. papernai* Kabata & Deets, 1988 and emphasised the importance of the presence of the secondary tine (referred to by Yamaguti (1936) as accessory claw) on the claw of the female second antenna, in addition to the absence of the dentiform posterior process of the maxillule, and the presence of the maxillary whip. Ho & Lin (2000) described new *Anuretes* and redefined both *Anuretes* and *Pseudanuretes*. They also transferred *A. chelatus* (Prabha & Pillai, 1986), *A. feddorni* Price, 1968 and *A. parvulus* Wilson, 1913 to the genus *Pseudanuretes*. Ho & Lin (2000: 231) indicated that *Pseudanuretes* lacks the postantennal process, but this was refined later by Dojiri & Ho (2013, see figure 123f) who clarified that in *P. chaetodontis* the postantennal process is lacking but the 3 sensillate papillae associated with this process are present.

Ho et al. (2008) divided the species of *Pseudanuretes* into two groups based on the shape of the apex of leg 4. The first group exhibits a spear-like structure and comprises *P. parvulus*, *P. chaetodontis*, *P.*

*fortipedis*, *P. pomacanthodi* and *P. papernai*. Members of the second, i.e. *P. pomacanthi*, *P. chelatus*, *P. indicus* and *P. schmitti* share a tipped with either one or two setae leg 4. Dojiri & Ho (2013) considered *P. feddorni* (Price, 1968) as a *species inquirendum*.

The new species, *P. anfoozi* n. sp., falls within the first group. The armature of the distal exopodal segment of leg 2 is I,6 whereas it is I,7 in *P. parvulus*, *P. chaetodontis* and *P. pomacanthodi*. The armature of the distal exopodal segment of leg 2 is unknown in *P. fortipedis*, and in *P. papernai* it is also I,6. Leg 5 of *P. papernai* has 4 setae (vs 3 setae in the new species), whereas leg 6 has 3 setae (vs 4 setae in the new species).

Moon & Kim (2012) redescribed *P. chaetodontis* based on males and females from *Chaetodontoplus septentrionalis* (Temminck & Schlegel) caught off Korea. In *P. chaetodontis*, leg 4 is a short process (not brachiform) as compared with the long proximal segment of the exopod in the new species.

*Pseudanuretes anfoozi* n. sp. can be readily distinguished from *P. parvulus* because the latter species lacks the maxillary whip and the fourth pedigerous somite is exposed in dorsal view. Although incompletely described, *P. fortipedis* can be distinguished from the new species by the presence of a second seta on the exopod of leg 4, in addition to the blade-like terminal element.

The new species is most closely related to *P. papernai*. Two descriptions exist for *P. papernai* and there are some differences between the two, which may indicate that two different species have been confused under the same name. The main differences between the descriptions are the shape of the female genital complex, and the relative lengths of the caudal setae, plus the minor differences mentioned by Ho et al. (2008).

The caudal ramus in both females and males of *P. anfoozi* n. sp. has only 5 caudal setae. This is an important difference from *P. papernai* which has 6 caudal setae. Also the caudal rami are shorter and wider in the new species. Therefore, the shape of the genital complex, the proportions of the caudal rami, and the number of caudal setae serve to separate *P. papernai* from *P. anfoozi* n. sp. In addition, the two species utilise different host species, *P. imperator* and *P. maculosus*, respectively.

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### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** All applicable institutional, national and international guidelines for the care and use of animals were followed.

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