

Morphological description of the parasitic copepod *Pandarus boscii* (Siphonostomatoidea: Pandaridae) found on the Picked dogfish *Squalus acanthias* (Squaliformes: Squalidae) in Turkish waters

Descripción morfológica del copépodo parásito, *Pandarus boscii* (Siphonostomatoidea: Pandaridae) encontrado en el galludo *Squalus acanthias* (Squaliformes: Squalidae) en los mares de Turquía

Ahmet Öktener¹*

¹Atalar 927 Street, 927 Sokak, n°1, 20150, Pamukkale, Denizli, Turkey

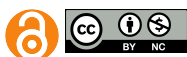
*ahmetoktener@yahoo.com

Resumen.- *Pandarus boscii* se reportó anteriormente en *Mustelus mustelus* (basónimo: *Squalus mustelus*), pero la descripción original de *P. boscii* fue incompleta e inadecuada. *P. boscii* se acepta actualmente como sinónimo de *Pandarus bicolor*. Las hembras de *P. boscii* se diferencian en que el color es incoloro o pálido (en *P. bicolor* el cefalotórax es marrón y el dorso amarillo), los segmentos primero y distal de la anténula presentan 23-25 setas plumosas y 12 setas, respectivamente (en *P. bicolor* son 24-26 setas plumosas y 13 setas), hoja mandibular con 7-8 dientes (en *P. bicolor* son 8 dientes), maxilípodo con una seta (en *P. bicolor* ausente), segmento exopodal proximal de la segunda pata con 5 espinas (en *P. bicolor* son 6 espinas). Se observaron diferencias significativas entre individuos machos de las dos especies, tales como: el cuerpo total más pequeño mide 3,5 mm de longitud (en *P. bicolor* 3,9 mm), los segmentos primero y distal de la anténula con 15-17 setas plumosas y 14 setas, respectivamente (en *P. bicolor* 26-27 setas plumosas y 12 setas), hoja mandibular con 7 dientes (en *P. bicolor* son 8), primer segmento de la antena con un proceso y maxilípodo con una seta (en *P. bicolor* ausente), la pata 5 con una seta desnuda y una plumosa (en *P. bicolor* 3 setas plumosas y una seta robusta), segmento exopodal distal de 3 y 4 patas con 2 espinas (en *P. bicolor* 4 espinas), segmento endopodal distal de 3 y 4 patas con 4 y 3 setas, respectivamente (en *P. bicolor* con 5 y 4 setas). Se proporciona una descripción detallada de *P. boscii* a partir de individuos hallados en la superficie corporal y aletas del galludo *Squalus acanthias*, recolectado recientemente en el Mar de Mármara, Turquía. Por tanto, de acuerdo a los resultados *Pandarus boscii* y *P. bicolor* son especies diferentes.

Palabras clave: *Pandarus*, *Squalus*, copépodo parásito, tiburón, Mar de Mármara

Abstract.- *Pandarus boscii* was previously reported in *Mustelus mustelus* (basonym: *Squalus mustelus*), but the original description of *P. boscii* was incomplete and inadequate. *P. boscii* is currently accepted as a synonym of *Pandarus bicolor*. Females of *P. boscii* differ in that the body is colorless or pale (in *P. bicolor* the cephalothorax is brown and the dorsum is yellow), the first and distal segments of the antennule have 23-25 plumose setae and 12 setae, respectively (in *P. bicolor* are 24-26 plumose setae and 13 setae), mandibular blade with 7-8 teeth (in *P. bicolor* are 8 teeth), maxilliped with one seta (in *P. bicolor* absent), proximal exopodal segment of the second leg with 5 spines (in *P. bicolor* are 6 spines). Significant differences were observed between male individuals of the two species, such as: smaller total body measuring 3.5 mm in length (in *P. bicolor* 3.9 mm), first and distal segments of the antennule with 15-17 plumose setae and 14 setae, respectively (in *P. bicolor* 26-27 plumose setae and 12 setae), mandibular blade with 7 teeth (in *P. bicolor* are 8), first antennal segment with one process and maxilliped with one seta (in *P. bicolor* absent), leg 5 with one naked and one plumose seta (in *P. bicolor* 3 plumose setae and a robust seta), distal exopodal segment of 3 and 4 legs with 2 spines (in *P. bicolor* 4 spines), distal endopodal segment of 3 and 4 legs with 4 and 3 setae, respectively (in *P. bicolor* with 5 and 4 setae). A detailed description of *P. boscii* is provided from individuals found on the body surface and fins of the spiny dogfish *Squalus acanthias*, recently collected in the Sea of Marmara, Turkey. Therefore, according to the results *Pandarus boscii* and *P. bicolor* are different species.

Key words: *Pandarus*, *Squalus*, parasitic copepod, shark, Sea of Marmara



INTRODUCTION

Pandarid copepods are external parasites, generally attaching in colonies on the body surface and fins of elasmobranchs (Yamaguti 1963). They are characterized by attachment extremities and adhesion pads, with rough surfaces facilitating strong attachment to the host (Kabata 1988). Fourteen species of *Pandarus* are listed as valid by WoRMS (2022). *Pandarus bicolor* Leach, 1816 was described parasitizing the tope shark *Galeorhinus galeus* (Linnaeus, 1758) from Torcross, Devon (London) by Leach (1816). This species is characterized by dark brown pigmented areas on the cephalothoracic segment, and caudal ramus scarcely visible in dorsal view. The morphological characteristics of this parasite have been given by various researchers (e.g., Leach 1816, Baird 1850, Scott 1900, Wilson 1907, 1932; Scott & Scott 1913, Barnard 1955, Cressey 1967, Hewitt 1967, Kabata 1979, 1992). Leach (1816) also reported *Pandarus boscii* from *Mustelus mustelus* (Linnaeus, 1758) (basonym: *Squalus mustelus*). Little is known about this species. Leach (1816) did not give a detailed description of this species. *P. boscii* has been considered as a variety or a synonym of *P. bicolor* due to deficiencies in the description of the parasite by Baird (1850), Brian (1906), Wilson (1907), Scott & Scott (1913), Hewitt (1967), Cressey (1967), Kabata (1979), Walter & Boxshall (2022).

Pandarus bicolor was reported for the first time in the Sea of Marmara, Turkey attached to the angular rough shark *Oxynotus centrina* (Squaliformes; Oxynotidae) and the picked dogfish *Squalus acanthias* (Squaliformes; Squalidae) (Öktener *et al.* 2020). Pale *Pandarus* individuals in other parasitological survey were observed, which may be *P. boscii*, according to the original description (see Leach 1816), however, to confirm the identity of the pale individuals, a complete description of this species is needed. The aim of this study is to give a detailed description of the morphological characters of *P. boscii*, which was inadequately described by Leach (1816), and to analyze what morphological characters of *P. boscii* are different in *P. bicolor* as presented by Kabata (1979).

MATERIALS AND METHODS

Sixty eight individuals of the picked dogfish were collected by commercial gillnets at the Sea of Marmara in 2021. Pandarid copepod parasites collected were fixed in 4% formaldehyde. Some individuals were cleared in lactic acid. Copepod specimens were dissected using a Wild M5 stereo microscope. Dissected appendages were mounted on slides in glycerin-gelatine mounting medium. All drawings were made with the aid of a drawing tube (Olympus® BH-DA). Microscope images were drawn on tracing paper. The drawings were scanned and digitized. Additionally, microphotographs were taken with the aid of a Canon® camera (EOS 1100D) connected to Olympus® CH30 Phase contrast microscope. Identifications and comparisons were performed according to

Cressey (1967), Hewitt (1967), and Kabata (1979). Scientific names, synonyms of parasites, and hosts were checked with WoRMS (2022), Froese & Pauly (2020), and Pollerspöck & Straube (2020). The samples of *P. boscii* (IUSHM 20231007-01, IUSHM 20231007-02) were deposited in the collections of the Istanbul University Museum (IUM), İstanbul, Turkey. The morphological characters of the specimens of *P. boscii* gathered in this study were compared with the measurements of *P. bicolor* given by Kabata (1979), and Öktener *et al.* (2020).

RESULTS

Order Siphonostomatoida Thorell, 1859

Family Pandaridae Milne Edwards, 1840

Genus *Pandarus* Leach, 1816

Type species. *Pandarus bicolor* Leach, 1816

Other species. *Pandarus ambiguus* (Scott T., 1907), *Pandarus brevicaudis* Dana, 1852, *Pandarus carcharhini* Ho, 1963, *Pandarus cranchii* Leach, 1819, *Pandarus floridanus* Cressey, 1967, *Pandarus katoi* Cressey, 1967, *Pandarus niger* Kirtisinghe, 1950, *Pandarus rhincodonicus* Norman, Newbound & Knott, 2000, *Pandarus rouxii* Risso, 1826, *Pandarus satyrus* Dana, 1849, *Pandarus sinuatus* Say, 1818, *Pandarus smithii* Rathbun, 1886, *Pandarus zygaenae* Brady, 1883

PANDARUS BOSCI LEACH, 1816 (FIGS. 1-8)

Pandarus boscii Leach, 1816: Leach 1816: p. 406, PI. XX, figs. 1-10. —Latreille 1818: p. 8, planche 335. —Lamarck 1818: p. 142. —Desmarest 1825: p. 339. —Guérin-Méneville 1829-1843: p. 41. —Milne-Edwards 1834-1840: p. 470. —Burmeister 1835: p. 331. —Lucas 1840: p. 297. —Baird 1850: p. 289. —Van Beneden 1892: p. 224. —Norman & Scott 1906: p. 211. —Wilson 1907: p. 400. —Boone 1930: p. 217. —Hewitt 1967: p. 21.

Host: *Squalus acanthias* Linnaeus, 1758 (Elasmobranchii, Squaliformes, Squalidae) (Fig. 1) in this study, and *Mustelus mustelus* in Leach (1816).

Locality: Turkey, Sea of Marmara, 40°31'43.8"N-27°12'11.2"E; (in this study), and London, Torcross, Devon by Leach (1816).

Habitat: anal fins, body surface in this study, and unknown in Leach (1816).

Number of examined fish: 68; number of infested fish: 8; number of parasite: 26 (10 female, 16 male); number of dissected parasite: 5 female, 10 male.

Prevalence: 11.8%; mean intensity: 3.3.

Differential diagnosis: The most important morphological character distinguishing *P. boscii* from *P. bicolor* is the pale color of the female and the spine and seta formulae of the 3rd and 4th legs of the male individual.

Description of female (Figs. 1b-4, Table 1): Body length 6.35 mm (6.2-6.4 excluding egg sac, n= 5). Cephalosome wider (2.5-3 mm; mean, 2.77 mm) than long (1.2-1.3 mm; mean, 1.24 mm). Second thoracic plate wider (2.3-2.43 mm; mean, 2.35 mm) than long (1.2-1.33 mm; mean, 1.25 mm). Third thoracic plate wider (1.5-1.7 mm; mean, 1.6 mm) than long (1-1.2 mm; mean, 1 mm). Fourth thoracic plate wider (2.3-2.5 mm; mean, 2.4 mm) than long (1.7-1.9 mm; mean,

1.8 mm). Genital complex longer (2-2.4 mm; mean, 2.2 mm) than wide (1.8-2.2 mm; mean, 2 mm). Abdomen a little longer (1-1.4 mm; mean, 1.2 mm) than wide (0.9-1.3 mm; mean, 1.1 mm). Dorsolateral plates of segment 2 not extending beyond the posterior edge of the plate of segment 3. There are several adhesion pads on different places of the female body as *P. bicolor*.

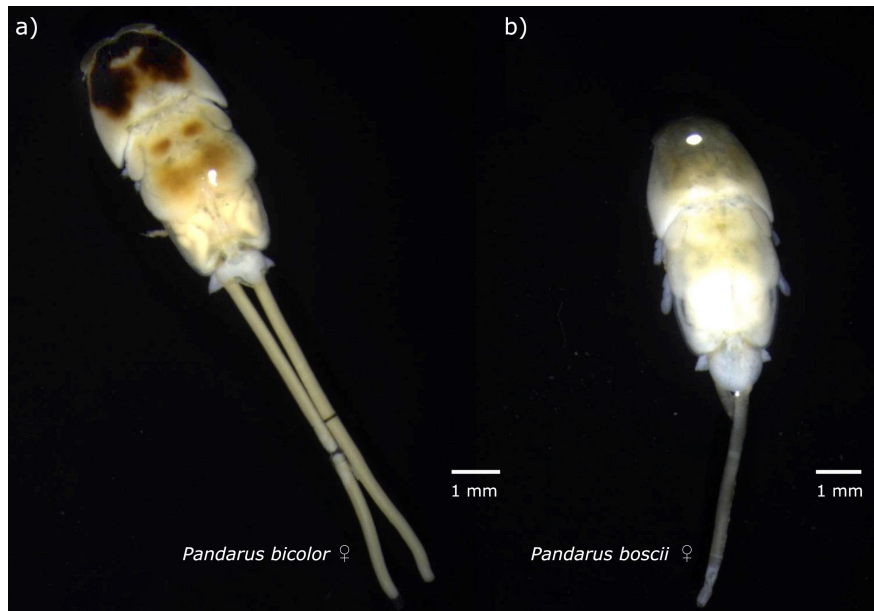


Figure 1. Female specimens of *Pandarus bicolor* (a) and *Pandarus boscii* (b). Scale bars: 1 mm / Especímenes hembras de *Pandarus bicolor* (a) y *Pandarus boscii* (b). Barras de escala: 1 mm

Table 1. Comparison of armature of legs 1-4 of adult female of *P. boscii* and ten pandarid species [the exopod of legs are showed before slash character (/) and the endopod after] / Comparación de la armadura de las patas 1-4 de una hembra adulta de *P. boscii* y diez especies de pandáridos [el exópodo de las piernas se muestra antes del slash (/) y el endópodo después]

Pandarids species	First leg	Second leg	Third leg	Fourth leg
<i>Pandarus bicolor</i> from Kabata (1979)	1-0; 3, I, 3 / 0-0; 3	0-1; VI-4 / 0-0; 5	0-1; III, 3, I / 0-0; 2	6 / 1
<i>Pandarus boscii</i> in this study	3, I, 3; 0-1 / 0-0; 3	0-1; V-4 / 0-0; 5	0-1; II, 4 / 0-0; 2	1, 4, I / 1
<i>Pandarus carcharhini</i> from Cressey (1967)	1-0; VI / 0-0; III	1-0; X / 0-0; VI	1-0; VII / 0-0; II	VIII / I
<i>Pandarus cranchii</i> from Izawa (2010)	1-0; III, I, 3 / 0-0; 3	1-0; III, I, 6 (5) / 0-0; 5 (4)	1-0; III, I, 2 / 0-0; 3 (2)	IV, I, 1 / 1
<i>Pandarus floridanus</i> from Cressey (1967)	1-0; IV-3 / 0-0; 3	1-1; IV-6 / 0-1; 8	1-1; IV-5 / 0-1; 6	1-1; IV-5 / 0-1; 5
<i>Pandarus katoi</i> from Cressey (1967)	1-0; VI / 0-0; III	1-0; X / 0-0; IV	1-0; VI / 0-0; II	VII / I
<i>Pandarus niger</i> from Cressey (1967)	1-0; VI / 0-0; III	1-0; X / 0-0; VII	1-0; VI / 0-0; III	VIII / II
<i>Pandarus rhincodonicus</i> from Norman et al. (2000)	0-0; VI-1 / 0-0; II-1	0-1; 0-10 / 0-0; 0-5	0-1; 0-6 / 0-0; 0-II	7 / 1
<i>Pandarus satyrus</i> from Cressey (1967)	1-0; VI / 0-0; III	1-0; X / 0-0; IV	1-0; VI / 0-0; II	VI / 0
<i>Pandarus simuatus</i> from Wilson (1907)	1-0; VI / 0-0; III	1-0; IX / 0-0; V	1-0; IV / 0-0; I	IV / 0
<i>Pandarus smithii</i> from Cressey (1967)	1-0; VI / 0-0; III	1-0; X / 0-0; IV	1-0; VI / 0-0; I	VI / I (0)

Antennule (Fig. 2a) 2-segmented; basal segment broader and longer than distal segment; basal segment with 23-25 plumose setae; distal segment with 5 long setae, 4 short digitiform setae, and 3 subapical setae. Maxilliped (Fig. 2b) 2-segmented; basal segment stout; terminal segment with spatulate tip, with seta and a spine. Maxilla (Fig. 2c) 2-segmented; lacertus unarmed, brachium slender; calamus longer than canna, clavus short. Maxillule (Fig. 2d) with 3 setae on palp and a robust process on endite. Mandible (Fig. 2e) with blade bearing 7-8 teeth. Antenna (Fig. 2f)

4-segmented; first segment shorter than the second segment; second segment unarmed; third segment with 1 medial and 1 subdistal spine; fourth segment transformed into a hook-shaped process. Caudal ramus (Fig. 2g) subtriangular, flattened, pointed distally, barely visible in dorsal view; armed with 1 spine and 1 seta on outer margin; 1 spine and 1 seta on inner margin and 1 apical spine. The fifth leg (Fig. 2h) bears 3 plumose and 2 naked setae. Setal and spinal formulae of legs 1-4 as in Table 1.

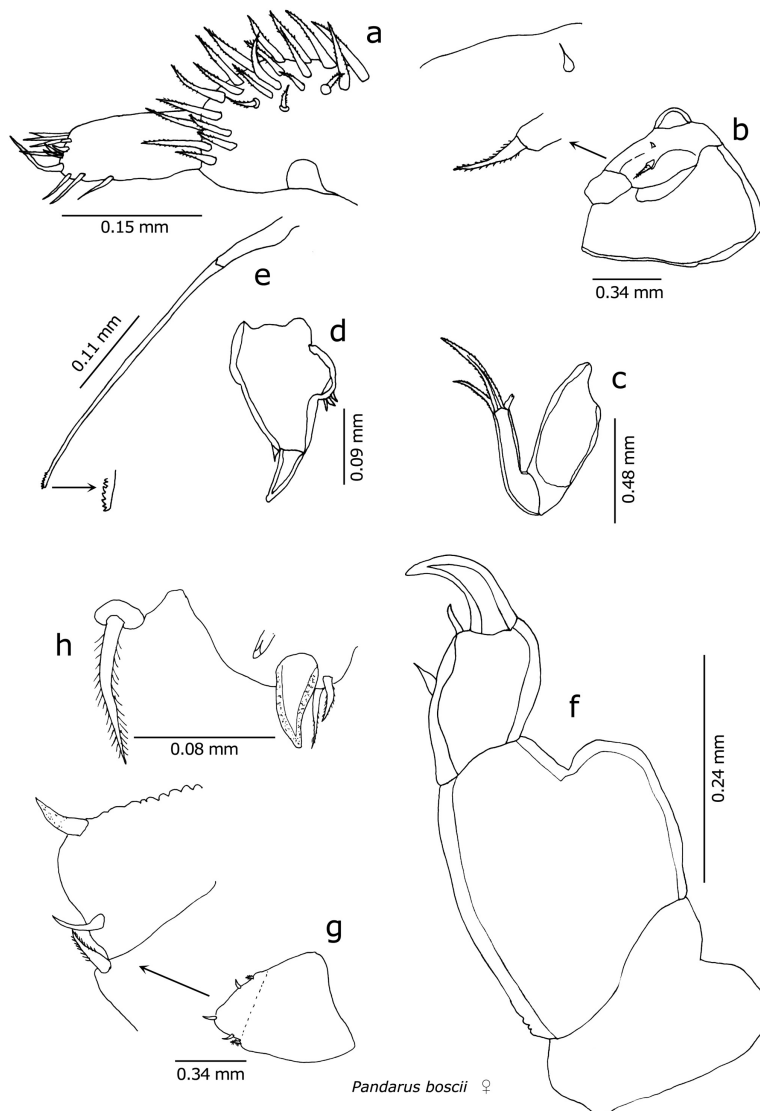


Figure 2. *Pandarus boscii*, female, a) antennule, b) maxilliped, c) maxilla, d) maxillule, e) mandible, f) antenna, g) caudal ramus, h) fifth leg / *Pandarus boscii*, hembra, a) anténula, b) maxilípido, c) maxilar, d) maxílula, e) mandíbula, f) antena, g) rama caudal, h) quinta pata

Leg 1 (Fig. 3a) with 2-segmented rami. Basis with 2 setae and 2 protrusion. Proximal exopodal segment shorter than distal segment, unornamented, unarmed; distal segment with 3 setae, densely spinulose anterolaterally. Proximal endopodal segment slightly shorter than distal segment; proximal segment unornamented, and armed with a seta; distal segment with a lateromedial area densely spinulose, with 7 elements (3 outer and 3 inner setae, and 1 apical bilobate spine).

Leg 2 (Fig. 3b) with 2-segmented rami. Proximal and distal exopodal segments subequal in length; both segments with outer patch of spinules as shown; proximal exopodal segment armed with a spine, densely spinulose anterolaterally; distal segment armed with 4 plumose setae and 5 spines, and ornamented with a densely spinulose anteromedial area.

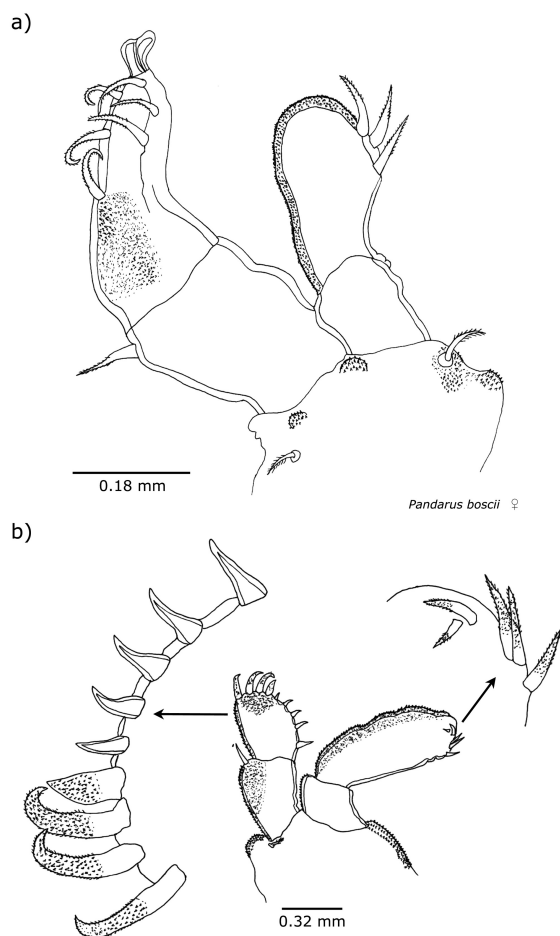


Figure 3. *Pandarus boscii*, female, a) first leg, b) second leg / *Pandarus boscii*, hembra, a) primera pata, b) segunda pata

Proximal endopodal segment shorter than distal segment; distal segment with a lateral outer patch of spinules; first segment unarmed; distal segment armed with 5 setae.

Leg 3 (Fig. 4a) with 2-segmented rami. Proximal exopodal segment shorter than distal segment; both segments with outer densely spinulose lateral patch; proximal exopodal segment with one, distal segment with 4 setae and 2 spines. Proximal endopodal segment shorter than distal segment; proximal segment unarmed; distal segment armed with two setae apically.

Leg 4 (Fig. 4b) with one-segmented rami. Proximal and distal exopodal segments partially fused. Exopod and endopod with densely spinulose lateral patch. Exopod with 5 setae and 1 spine; endopod with 1 apical seta.

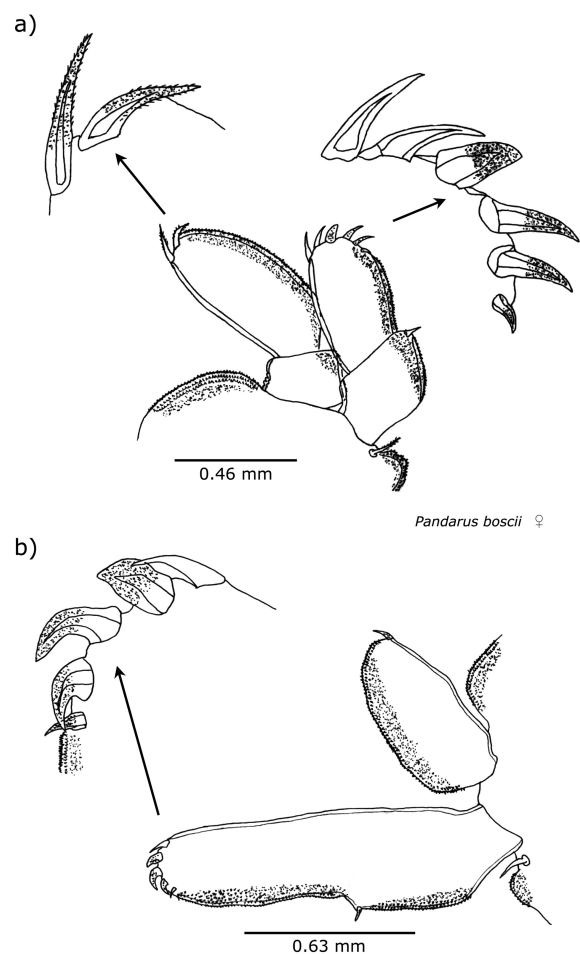


Figure 4. *Pandarus boscii*, female, a) third leg, b) fourth leg / *Pandarus boscii*, hembra, a) tercera pata, b) cuarta pata

Description of male (Figs. 5-8, Table 2): Body length 3.5 mm (3.2-3.8 excluding caudal ramus, n= 7). Dorsal shield longer (1.7-1.2.1 mm; mean, 1.9 mm) than wide (1.5-1.7 mm; mean, 1.6 mm). Second thoracic plate wider (1-1.1 mm; mean, 1.1 mm) than long 0.6 mm. Third thoracic plate wider 0.8 mm than long 0.3 mm. Fourth thoracic plate wider (0.7-0.8 mm; mean, 0.8 mm) than long 0.4 mm. Genital complex little longer (0.7-0.8 mm; mean, 0.75 mm) than wide 0.7 mm. Abdomen a little wider (0.3-0.4 mm; mean, 0.35 mm) than long 0.2 mm. Caudal ramus as long as wide (0.2 mm).

Antennule (Fig. 6a) 2-segmented; basal segment broader and longer than distal segment, the former with 15-17 lightly plumose setae, the later with 3 subapical long plumose setae, 3 long plumose setae, 3 long, and 4 naked setae. Mandible (Fig. 6b), and maxilla (Fig. 6e) as in female. Maxillule (Fig. 6c) bears 1 naked and 2 plumose setae on palp, and a robust process on endite. Antenna (Fig. 6f) 4-segmented; first segment with a process; second segment slightly longer than first, unarmed; third segment with 1 medial and 1 subdistal spine; fourth segment transformed into a hook-shaped process. Maxilliped (Fig. 6d) with corpus with one small pad on anterior protrusion; subchela with a seta, without posterior swelling; terminal segment with a densely spinulose posterior area. Caudal ramus (Fig. 6g) bears 2 small and 4 long pinnate setae distally and a medial row of setules. Leg 5 (Fig. 6h) with one naked and one plumose seta. Setal and spinal formulae of legs 1-4 as in Table 2.



Figure 5. *Pandarus boscii*, microphotograph of a male specimen / *Pandarus boscii*, microfotografía de un ejemplar macho

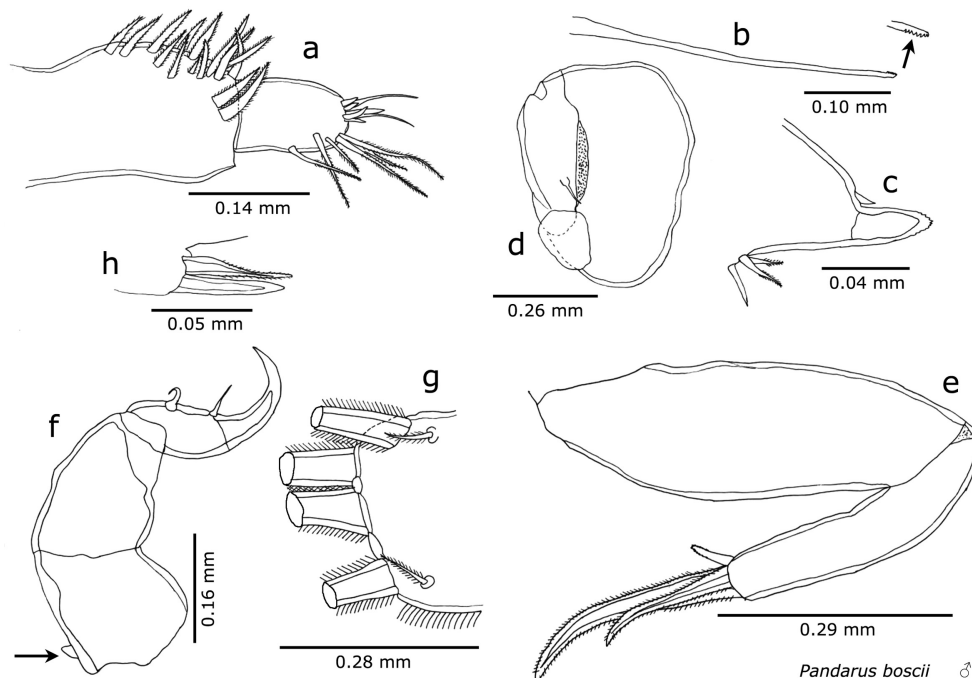


Figure 6. *Pandarus boscii*, male, a) antennule, b) mandible, c) maxillule, d) maxilliped, e) maxilla, f) antenna, g) caudal ramus, h) fifth leg / *Pandarus boscii*, macho, a) anténula, b) mandíbula, c) maxílula, d) maxilípido, e) maxilar, f) antena, g) rama caudal, h) quinta pata

Table 2. Comparison of armature of legs 1-4 of adult male of *P. boscii* and ten pandarid species [the exopod of legs are showed before slash character (/) and the endopod after] / Comparación del esqueleto de las piernas 1-4 del macho adulto de *P. boscii* y diez especies de pandáridos [el exópodo de las piernas se muestra antes del slash (/) y el endópodo después]

Pandarids species	First leg	Second leg	Third leg	Fourth leg
<i>Pandarus ambiguus</i> from Scott (1907)	0-0; IV-3 / 0-0; 0-3	I-1; IV-5 / 0-1; 0-7	I-0; III-4 / 0-1; 0-4	IV;3 / 0-1; 0-3
<i>Pandarus bicolor</i> from Kabata (1979)	I-0; IV-3 / 0-0; 0-3	I-1; IV-5 / 0-1; 0-8	I-1; IV-5 / 0-1; 0-5	I-1; IV-5 / 0-1; 0-4
<i>Pandarus boscii</i> in this study	I-0; IV-3 / 0-0; 0-3	I-1; IV-5 / 0-1; 0-7	I-0; II-5 / 0-1; 0-4	I-0; II-4 / 0-1; 0-3
<i>Pandarus brevicaudis</i> from Wilson (1907)	I-0; IV-3 / 0-0; 0-3	I-1; III-6 / 0-1; 0-6	0-1; III-6 / 0-1; 0-6	I-1; 0-6 / 1-1; 0-4
<i>Pandarus cranchii</i> from Izawa (2010)	I-0; IV-3 / 0-0; 0-3	I-1; IV-6 / 0-1; 0-8	I-1; IV-5 / 0-1; 0-6	I-1; IV-5 / 0-1; 0-5
<i>Pandarus floridanus</i> from Cressey (1967)	I-0; IV-3 / 0-0; 0-3	I-1; IV-6 / 0-1; 0-8	I-1; IV-5 / 0-1; 0-6	I-1; IV-5 / 0-1; 0-5
<i>Pandarus katoii</i> from Cressey (1967)	I-0; IV-3 / 0-0; 0-3	I-1; III-6 / 0-1; 0-8	I-1; IV-5 / 0-1; 0-6	I-1; IV-5 / 0-1; 0-5
<i>Pandarus rhincodonicus</i> from Norman <i>et al.</i> (2000)	I-0; IV-3 / 0-0; 0-3	I-1; IV-5 / 0-1; 0-8	I-1; IV-5 / 0-1; 0-5	I-0; IV-5 / 0-1; 0-4
<i>Pandarus satyrus</i> from Cressey (1967)	I-0; IV-3 / 0-0; 0-3	I-1; IV-6 / 0-1; 0-8	I-1; IV-5 / 0-1; 0-6	I-1; IV-5 / 0-1; 0-5
<i>Pandarus sinuatus</i> from Wilson (1907)	I-0; IV-3 / 0-0; 0-3	I-1; IV-6 / 0-1; 0-8	I-1; IV-5 / 0-1; 0-5	I-1; IV-5 / 1-1; 0-5
<i>Pandarus smithii</i> from Wilson (1907)	I-0; IV-3 / 0-0; 0-3	I-1; IV-4 / 0-1; 0-8	I-1; IV-5 / 0-1; 0-5	I-0; IV-5 / 0-1; 0-5

Leg 1 (Fig. 7a) with 2-segmented rami. Proximal exopodal segment longer than distal segment, the former with one outer spine, the latter with 4 spines and 3 plumose setae. Proximal endopodal segment shorter than distal segment; proximal segment unarmed, distal segment with 3 plumose setae.

Leg 2 (Fig. 7b) with 2-segmented rami. Proximal exopodal segment slightly longer than distal segment, the former with one outer spine and one plumose inner seta, and with a densely spinulose outer patch; distal segment with 4 spines and 5 plumose setae. Distal endopodal segment longer than proximal segment, the latter with one inner plumose seta, the former with 7 setae.

Leg 3 (Fig. 7c) with 2-segmented rami. Proximal and distal segments subequal in length, the former with one outer spine, the latter with two spines and five setae. Proximal endopodal segment shorter than distal segment, the former with one plumose inner seta, the latter with 4 plumose setae.

Leg 4 (Fig. 7d) with 2-segmented rami. Proximal exopodal segment slightly longer than distal segment, the former with one outer spine, the latter with 2 spines and 4 plumose setae. Proximal endopodal segment armed with one inner, distal endopodal segment armed with 3 plumose setae.

Remarks: *Pandarus boscii* was reported on *Mustelus mustelus* (basonym: *Squalus mustelus*) by Leach (1816). Leach (1816) described this species as pale, and gave some drawings such as body, antenna, and legs 1-7. Unfortunately, most of the descriptions given by Leach (1816) are not very

obvious and informative. Also, he did not give a detailed description of its morphology. Baird (1850) regarded *P. boscii* as separate species, but noticed *P. boscii* is extremely similar to *P. bicolor*. He suggested that this species well be a variety of *P. bicolor*. He noticed also that *P. boscii* does not have black spots, is pale in color, and that it is smaller than *P. bicolor*. Since then, *P. boscii* has been considered as a synonym due to deficiencies in the description of the parasite (Brian 1906, Wilson 1907, Scott & Scott 1913, Hewitt 1967, Cressey 1967, Walter & Boxshall 2022).

DISCUSSION

Picked dogfish, *Squalus acanthias* Linnaeus, 1758 (Elasmobranchii, Squaliformes, Squalidae) is a benthopelagic and oceanodromous shark. It feeds on demersal fishes, demersal crustaceans, and several invertebrates (Froese & Pauly 2020). Twenty-five parasitic copepod species were reported from picked dogfish. Twelve of twenty-five parasitic copepod species belong to the family Pandaridae. Three species of *Pandarus*, *P. ambiguus*, *P. bicolor*, and *P. cranchii* have been reported from picked dogfish (WoRMS 2022).

Pandarus bicolor samples having two colors and *P. boscii* having pale-color matching with Leach (1816)'s description were found in this study. After dissection of the species, it was possible to confirm that *P. boscii* and *P. bicolor* are morphologically different.

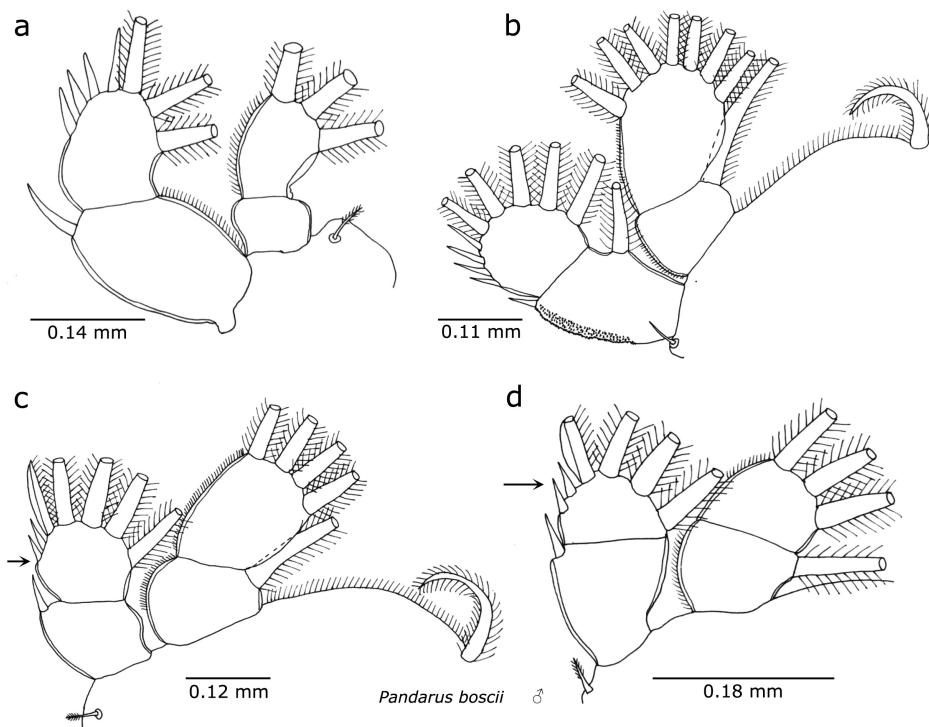


Figure 7. *Pandarus boscii*, male, a) first leg, b) second leg, c) third leg, d) fourth leg / *Pandarus boscii*, macho, a) primera pata, b) segunda pata, c) tercera pata, d) cuarta pata

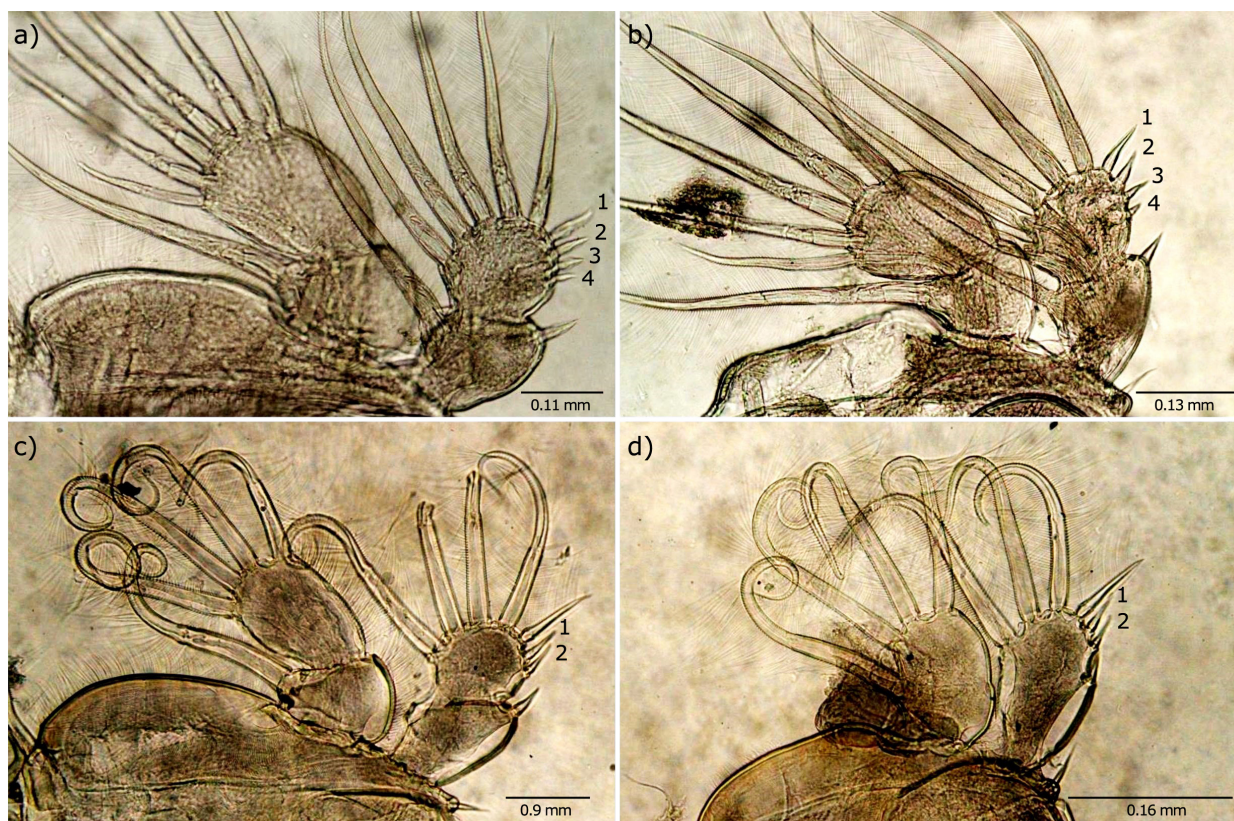


Figure 8. Setal and spinal formulae of legs 3-4 of *Pandarus bicolor* (a, b) and *Pandarus boscii* (c, d) / Fórmula de setas y espinas de las patas 3-4 de *Pandarus bicolor* (a, b) y *Pandarus boscii* (c, d)

The morphology of the female of *P. bicolor* has been studied by various researchers (e.g., Baird 1850, Scott 1900, Scott & Scott 1913, Barnard 1955, Cressey 1967, Hewitt 1967, Kabata 1979, 1992; Öktener *et al.* 2020). In this study, it was possible to collect and examine female individuals of *P. bicolor* and *P. boscii*. The morphological characters of *P. boscii* observed in this study were compared with the findings of *P. bicolor* presented by Kabata (1979), and Öktener *et al.* (2020). In females, the maxillule, maxilla, and antenna of *P. boscii* are similar to those of *P. bicolor*. The following differences were observed between *P. boscii* and *P. bicolor*: number of setae on the first and distal antennular segments (24-26 plumose setae in *P. bicolor*, but 23-25 setae in *P. boscii* and 13 setae in *P. bicolor*, but 12 setae in *P. boscii*, respectively), number of teeth on the mandibular blade (8 in *P. bicolor*, but 7-8 teeth in *P. boscii*), and the occurrence of a seta on the maxilliped of *P. boscii* (absent in *P. bicolor*). Minor differences were also found in the spinal and setal formulae of the exopods and endopods of the legs of both species, for example; there are 5 spines on the proximal exopodal segment of the second leg of *P. boscii*, but 6 spines are present in *P. bicolor*.

No published descriptions or drawings of the male of *P. boscii* are available. Kabata (1979) mentioned that the male of *P. bicolor* is not well known, and indicated that there are discrepancies in the armature formula of the legs given by various authors. Kabata (1979) indicated the uncertainty in the number of setae and spines on the exopod and endopod of the legs of *P. bicolor* with a question mark. In this work, male and females of *P. boscii* were studied and the discrepancies highlighted by Kabata (1979) are resolved.

The maxillule and maxilla of the males of *P. boscii* are similar to those of the males of *P. bicolor*, but several morphological differences were observed between the males of *P. boscii* and *P. bicolor*. The differences between the males of *P. boscii* and *P. bicolor* are: the total body length (3.5 mm in *P. boscii*, 3.9 mm in *P. bicolor*), the number of setae on the first and distal segments of the antennule (26-27 plumose setae in the first antennular segment in *P. bicolor*, but 15-17 setae in *P. boscii*; 12 setae in the distal antennular segment of *P. bicolor*, but 14 setae in *P. boscii*), the number of teeth of the mandibular blade (8 teeth in *P. bicolor*, but 7 in *P. boscii*), presence of a process on the first segment of the antenna in *P. boscii*, (absent in *P. bicolor*), presence of a seta on the maxilliped of *P. boscii*, (absent in *P. bicolor*), number of setae on leg 5 (3 plumose setae and one stout seta in *P. bicolor*, but one naked and one plumose seta in *P. boscii*).

Major differences were detected in the number of spines and setae of exopods and endopods of swimming legs in both species. The distal exopodal segment of third and fourth legs are armed with two spines in *P. boscii*, but with four spines in *P. bicolor*. The distal endopodal segment of third and fourth legs are armed with four and three setae, respectively, in *P. boscii*, but with five and four setae, respectively, in *P. bicolor* (Fig. 8).

P. cranchii female differs noticeably from *P. boscii* in having eyespots separated in fully pigmented forms, dorsal plate of thoracic segment 2 extending well beyond the posterior edge of the plate of segment 3 according to Cressey (1967). Differences in mouthparts of the females of *P. boscii* and *P. cranchii* are: the number of setae on the first and distal segments of the antennule (26 plumose setae in the first antennular segment in *P. cranchii*, but 23-25 setae in *P. boscii*; 11 setae in the distal antennular segment of *P. cranchii*, but 12 setae in *P. boscii*), the number of teeth of the mandibular blade (10 teeth in *P. cranchii*, but 7-8 in *P. boscii*), the number of segments of the antenna (5 segments in *P. cranchii*, but 4 segments in *P. boscii*); the number of seta on the maxillule (2 setae on and a stout seta in *P. cranchii*; 3 setae and a robust process in *P. boscii*). The differences among setal and spinal formulae of legs 3-4 of males of *P. boscii* and *P. cranchii* are: 2 spines on the second exopodal in *P. boscii*, but 4 spines in *P. cranchii*.

Pandarus ambiguus (nomen dubium *Nogagus ambiguus*) was described from male individuals collected from piked dogfish (*Squalus acanthius*) caught from the North Sea in 1902 by Scott (1907). The males of *P. boscii* and *P. ambiguus* can be easily distinguished by the number of setae on the antennule, and armature and shape of maxilliped (with or without terminal claws). The setal and spinal formulae of the exopod, and endopod of legs 1 and 2 is the same for both species. However, the setal formulae of the third and fourth legs of these two species is different. Two spines on the second exopodal segment are present in *P. boscii*, but 4 spines are present in *P. ambiguus*.

The following color differences in female body were observed between *P. boscii* and other pandarids: colorless or pale without pigmentation in *P. boscii* (Leach, 1816), but creamy yellow to dark brown and cephalon usually heavily pigmented in *P. bicolor* (from Kabata 1979), creamy yellow with dark brown pigmentation in *P. carcharhini*, creamy yellow with light brown pigmentation in *P. floridanus* and *P. katoi*, dark brown except where unpigmented in *P. niger*, a rich brownish black, the margins of the carapace and of the dorsal plates in *P. smithii*, creamy white except for some light brown pigmentation (from Cressey 1967), dull yellow or yellowish white or dark brown to black with eye spots in *P. sinuatus* (from Wilson 1907, Cressey 1967), dark chocolate chestnut brown in *P. rhincodonicus* (from Norman *et al.* 2000), a chocolate-brown blotch covering the center of the carapace, dark brown to black with eye spots in *P. satyrus*; yellowish brown in *P. brevicaudis*, light brownish yellow, more or less covered with dark brown-black pigment in *P. cranchii* (from Wilson 1907).

The females of 14 pandarid species (except of *P. bicolor*) differs noticeably from the female of *P. boscii* in the dorsal plate of thoracic segment 2 reaching well beyond the posterior edge of the plate of segment 3 (Wilson 1907, Cressey 1967).

The males of *P. carcharhini*, *P. niger*, *P. rouxii*, and *P. zyganae* remain unknown and have not been compared to *P. boscii*. The legs 1 and 2 of *P. boscii* and the other 10 *Pandarus* species (*P. ambiguus*, *P. bicolor*, *P. brevicaudis*, *P. cranchii*, *P. floridanus*, *P. katoi*, *P. rhincodonicus*, *P. satyrus*, *P. sinuatus*, *P. smithii*) are very similar. However, some obvious differences were observed in the second exopodal segment of legs 3 and 4. *P. boscii* differs from the other species that it has distal exopodal segment of 3 and 4 legs with 2 spines and distal endopodal segment of 3 and 4 legs with 4 and 3 setae, respectively. These differences are seen in Table 2.

Baird (1850) suggested that *P. boscii* is most probably a variety of *P. bicolor*, which prompted other authors (e.g., Brian 1906, Wilson 1907, Scott & Scott 1913, Hewitt 1967, Cressey 1967, Kabata 1979, Walter & Boxshall 2022) to consider the former as a synonym of the latter. In this study, the morphological differences of male and female individuals of *P. boscii* are revealed for the first time through a complete description of *P. boscii* and compared with those of *P. bicolor*. In addition, uncertainties about the leg morphology of *P. bicolor* mentioned by Kabata (1979) are clarified in this study. Recently, Palomba *et al.* (2022) presented the molecular characterization of some pandarid copepods found in Mediterranean sharks. Thus, genetic and molecular studies of *Pandarus boscii* are likely to be carried out in the future for confirmation of the species.

ACKNOWLEDGMENT

The author gratefully acknowledge Dr. Mike Robertson for technical support.

LITERATURE CITED

- Baird W. 1850.** The natural history of the British Entomostraca. pp. 1-8, 1-364. The Ray Society, London. <doi:10.5962/bhl.title.39641>
- Barnard KH. 1955.** South African parasitic Copepoda. Annals of the South African Museum. Annale van die Suid-Afrikaanse Museum 41: 223-312.
- Boone L. 1930.** Scientific results of the cruises of the yachts "Eagle" and "Ara", 1921-1928, William K. Vanderbilt, commanding. Crustacea: Anomura, Macrura, Schizopoda, Isopoda, Amphipoda, Mysidacea, Cirripedia and Copepoda, 221 pp. Huntington, New York. <doi:10.5962/bhl.title.4467>
- Brady GS. 1883.** Report on the Copepoda collected by H.M.S. Challenger during the years 1873-76. Report on the Scientific Results of the Voyage of H.M.S. Challenger during the Years 1873-76, Zoology 8 (Part 23): 1-142. <https://doi.org/10.5962/bhl.title.59771>
- Brian AGG. 1906.** Copepodi parassiti dei pesci d'Italia, 187 pp. Stabilimento Tipo-Litografico Regio Istituto Sordomuti, Genova.
- Burmeister H. 1835.** Beschreibung einiger neuen oder weniger bekannten Schmarotzerkrebse, nebst allgemeinen Betrachtungen über die Gruppe, welcher sie angehören. Nova Acta Physico-Medica Academiae Caesareae Leopoldino-Carolinae Naturae Curiosorum (Acta der Kaiserlichen Leopoldinisch-Carolinischen Deutschen Akademie der Naturforscher), Halle 17(1): 269-336. <doi:10.5962/bhl.title.39131>
- Cressey RF. 1967.** Revision of the family Pandaridae (Copepoda: Caligoida). Proceedings of the United States National Museum 121: 1-133. <doi:10.5479/si.00963801.121-3570.1>
- Desmarest AG. 1825.** Considérations générales sur la classe des crustacés et description des espèces de ces animaux, qui vivent dans la mer, sur les côtes, ou dans les eaux douces de la France, 446 pp. F.G. Levrault, Paris. <doi:10.5962/bhl.title.10029>
- Froese R & D Pauly. 2020.** FishBase. <www.fishbase.org>
- Guérin-Méneville FE. 1829-1837.** Crustacés. In: Iconographie du Règne animal de G. Cuvier, ou représentation d'après nature de l'une des espèces les plus remarquables et souvent encore non figurées, de chaque genre d'animaux. Avec un texte descriptif mis au courant de la science. Ouvrage pouvant servir d'atlas a tous les traités de zoologie, 48 pp. J.B. Baillièrre, Libraire de l'Académie Royale de Médecine, Paris. <doi:10.5962/bhl.title.10331>
- Hewitt GC. 1967.** Some New Zealand parasitic Copepoda of the family Pandaridae. New Zealand Journal of Marine and Freshwater Research 1: 180-264. <doi:10.1080/00288330.1967.9515202>
- Izawa K. 2010.** Redescription of eight species of parasitic copepods (Siphonostomatoida, Pandaridae) infecting Japanese elasmobranchs. Crustaceana 83(3): 313-341. <doi:10.1163/001121609X12591347509329>
- Kabata Z. 1979.** Parasitic copepoda of the British fishes, 468 pp. The Ray Society Publications, The British Museum, London.
- Kabata Z. 1988.** Copepoda and Branchiura. In: Margolis L & Z Kabata (eds). Guide to the parasites of fishes of Canada. Part II - Canadian Special Publication of Fisheries and Aquatic Sciences 101: 3-127.
- Kabata Z. 1992.** Copepods parasitic on fishes. Synopses of the British fauna, New Series 47: 1-264. Universal Book Services/W. Backhuys, Oegstgeest.
- Lamarck JBPAM. 1818.** Histoire naturelle des animaux sans vertèbres: présentant les caractères généraux et particuliers de ces animaux, leur distribution, leurs classes, leurs familles, leurs genres, et la citation des principales espèces qui s'y rapportent: précédée d'une introduction offrant la détermination des caractères essentiels de l'animal, sa distinction du végétal et des autres corps naturels, enfin, l'exposition des principes fondamentaux de la zoologie. Tome 5. Classe Huitième. Les Crustacés (Crustacea), 612 pp. Deterville / Verdière Paris. <doi:10.5962/bhl.title.40014>
- Latreille M. 1818.** Tableau encyclopédique et méthodique des trois règnes de la nature. Vingt-quatrième partie. Crustacés, arachnides et insectes, 521 pp. Agasse, Paris. <doi:10.5962/bhl.title.7834>

- Leach WE. 1816.** Annulosa. In: Encyclopedia Britannica, Vol 1 of 5, supplement to the fourth, fifth and sixth editions 1(2): 401-453. The Ray Society, London.
- Lucas PH. 1840.** Histoire naturelle des crustacés, des arachnides et des myriapodes. Ouvrage accompagné de 46 planches gravées sur acier représentant plus de 300 sujets. Histoire naturelle des animaux articulés, annélides, crustacés, arachnides, myriapodes et insectes, 600 pp. P. Duménil, Paris. <doi:10.5962/bhl.title.44485>
- Milne-Edwards H. 1834-1840.** Histoire naturelle des crustacés, comprenant l'anatomie, la physiologie et la classification de ces animaux 3: 1-638. Librairie Encyclopédique Roret, Paris. <doi:10.5962/bhl.title.16170>
- Norman AM & T Scott. 1906.** The crustacea of Devon and Cornwall, 232 pp. William Wesley and Son, London. <doi:10.5962/bhl.title.1939>
- Norman BM, DR Newbound & B Knott. 2000.** A new species of Pandaridae (Copepoda), from the whale shark *Rhincodon typus* (Smith). Journal of Natural History 34(3): 355-366. <doi:10.1080/002229300299534>
- Öktener A, D Ventura & M Şirin. 2020.** Occurrence of *Pandarus bicolor* (Siphonostomatoida: Pandaridae) on vulnerable shark species: *Oxynotus centrina* and *Squalus acanthias* from Turkish marine waters. Vie et Milieu 70: 19-31.
- Palomba M, G Insacco, B Zava & M Santoro. 2022.** Occurrence and molecular characterization of some parasitic copepods (Siphonostomatoida: Pandaridae) on pelagic sharks in the Mediterranean Sea. Frontiers in Marine Science 8, 778034. <doi:10.3389/fmars.2021.778034>
- Pollerspöck J & N Straube. 2020.** Shark-References.com Bibliography Database of living/fossil sharks, rays and chimaeras (Chondrichthyes: Elasmobranchii, Holocephali). <www.shark-references.com>
- Scott T. 1900.** Notes on some crustacean parasites of fishes. Part III: 144-189. Scientific Investigations-Eighteenth Annual Report of the Fishery Board for Scotland. Printed for Her Majesty's Stationery Office Press, London.
- Scott T. 1907.** Some additional notes on Copepoda from the Scottish seas. Report of the Fishery Board of Scotland 25(3): 209-220.
- Scott T & A Scott. 1913.** The British parasitic Copepoda. Volumes I and II: 1-257. Ray Society, London. <doi:10.5962/bhl.title.58672>
- Van Beneden PJ. 1892.** Le male de certains caligides et un nouveau genre de cette famille. Bulletins de L'Académie Royale des Sciences, des Letters et des Beaux-Arts de Belgique, 3 serie 23(3): 220-235.
- Walter TC & G Boxshall. 2022.** World of copepods database. *Pandarus boscii* Leach, 1816. Accessed through: World Register of Marine Species. <https://www.marinespecies.org/aphia.php?p=taxdetails&id=359772 on 2022-04-13>
- Wilson CB. 1907.** North American parasitic copepods belonging to the family Caligidae. Parts 3 and 4- A revision of the Pandarinae and the Cecropinae. Proceedings of the United States National Museum 33: 323-490. <doi:10.5479/si.00963801.33-1573.223>
- Wilson CB. 1932.** The copepods of the Woods Hole region, Massachusetts. Bulletin of the United States National Museum 158: 1-635. <doi:10.5479/si.03629236.158.i>
- WoRMS. 2022.** World register of marine species. Vliz, Oostende. <http://www.marinespecies.org>
- Yamaguti S. 1963.** Parasitic copepoda and branchiura of fishes, 1104 pp. Wiley Interscience, New York.

Received 9 November 2021

Accepted 15 May 2022