VIE ET MILIEU - LIFE AND ENVIRONMENT, 2020, 70 (1): 19-31

OCCURRENCE OF *PANDARUS BICOLOR* (SIPHONOSTOMATOIDA: PANDARIDAE) ON VULNERABLE SHARK SPECIES: *OXYNOTUS CENTRINA* AND *SQUALUS ACANTHIAS* FROM TURKISH MARINE WATERS

A. ÖKTENER[1], D. VENTURA[2], M. ŞIRIN[1]*

[1] Department of Fisheries, Sheep Research Institute, Çanakkale Road 7km., 10200, Bandirma, Balikesir, Turkey
[2] Department of Environmental Biology, University of Rome "La Sapienza", V. le dell'Università 32, 00185 Rome, Italy
** Corresponding author: ahmetoktener@yahoo.com*

OXYNOTUS CENTRINA
SQUALUS ACANTHIAS
PANDARUS BICOLOR
SEA OF MARMARA
TURKEY

ABSTRACT. – The angular rough shark *Oxynotus centrina* (Squaliformes; Oxynotidae) and the picked dogfish *Squalus acanthias* (Squaliformes; Squalidae) are known as vulnerable deep-sea shark species by the International Union Conservation Nature (IUCN). *Pandarus bicolor* (Copepoda, Pandaridae) is reported for the first time on angular rough shark and picked dogfish from Turkish waters, during a demersal fish stock assessment in the Sea of Marmara. This parasitic copepod was found both on the body surface and fins of the hosts. Although this parasite is reported from several shark species, its occurrence has never been reported from the angular rough shark in the world. In this paper, morphological characters belonging to *P. bicolor* samples were assessed and described through photos and drawings.

INTRODUCTION

The total length of the Turkish coast is 8,333 km, including the Black Sea, the Mediterranean Sea, the Aegean Sea and the Sea of Marmara (Kiliç 1999). The Sea of Marmara is a small continental sea located between the Aegean Sea and the Black Sea, connected to these seas by the Dardanelles Strait and the Bosphorus Strait, respectively (Gerin *et al.* 2013). The marine fish diversity of Turkish waters includes 512 fish species. Among these species, 257 species were reported only in the Sea of Marmara (Bilecenoğlu *et al.* 2014).

Fish parasites harbour a large number of highly diverse species. Despite its high fish diversity, the parasite community in the Sea of Marmara has not been investigated thoroughly. However, Akmirza (2016) reported 59 species (7 monogeneans, 19 digeneans, 6 cestodes, 3 nematodes, 5 acanthocephalans, 2 hirudineans, 8 copepods and 9 isopods) in his checklist of parasite species from the Sea of Marmara. This number of parasite species is very low compared to the total number of fish species (257) reported for the Sea of Marmara.

The angular rough shark *Oxynotus centrina* (Linnaeus, 1758) is a rare and deep-sea shark. It is found across continental shelves and upper slopes at depths between 30 and 800 m (Kabasakal 2009). Its distribution includes the eastern Atlantic, the Mediterranean Sea and the Sea of Marmara (Serena 2005). This species has no economic importance in the Mediterranean Sea, being a non-target species both for professional and recreational fisheries. It is generally a bycatch species, often discarded because local fishermen believe that it brings bad luck. Globally, the angular rough shark is considered as a vulnerable species by the World Conservation Union's Red List of Threatened Animals (Bradai *et al.* 2007, IUCN 2018). Although there are several studies about the reproductive biology (Capapé *et al.* 1999), feeding habits (Barrull & Mate 2001, Capapé 2008), morphology (Megalofonou & Dalamas 2004) and distribution (Dragicevic *et al.* 2009) of *Oxynotus centrina*, there are very little data concerning its parasite fauna. In fact, only two cestode species (*Gymnorhynchus gigas*, *Molicola* sp.) were listed by Pollerspöck & Straube (2018). Other records concerning the parasite species affecting *O. bruniensis* are reported in Beverley-Burton *et al.* (1987) and Whittington & Kearn (2011).

The picked dogfish, *Squalus acanthias*, is distributed worldwide, including the Atlantic continental shelf (Menni & Lopez 1984). It is a viviparous species, that forms schools segregated by size and sex (Alonso *et al.* 2002). Twenty-three parasitic copepods species were listed from picked dogfish by WoRMS (2019). There are several records of *P. bicolor* on *S. acanthias* reported by various researchers (Hewitt 1967, Boxshall 1974, Henderson *et al.* 2002).

Representatives of the family Pandaridae include ectoparasitic copepods on the fins and body surface of elasmobranch hosts. Members of this family have characteristic attachment organs, named adhesion pads, with rough surfaces facilitating strong attachment to the host (Kabata 1988). The adhesive surface of the pad is formed of a thick cushion of skin whose outer layer is raised into ridges similar to those in the epidermis on the palms of our hands (Wilson 1907). A total of 64 species belonging to 23 genera of Pandaridae were listed by Walter & Boxshall (2019). Several studies mention pathological effects of pandarid species on their hosts (Benz 1980, Benz & Adamson 1990, Borucinska & Benz 1999). Therefore, the parasite diversity of *O. centrina* should be more deeply investigated to better understand the biology of this little-known shark. In this study, we present for the first time the occurrence of *P. bicolor* Leach, 1816 on the angular rough shark. We also report data regarding the infestation rates of *P. bicolor* on *S. acanthias*.

MATERIALS AND METHODS

The angular rough shark, *Oxynotus centrina* (Linnaeus, 1758) (Squaliformes; Oxynotidae) (n = 16) and the picked dogfish *Squalus acanthias* Linnaeus, 1758 (Squaliformes; Squalidae) (n = 126) were caught in nets by trawling in the Sea of Marmara, Turkey during a demersal fish stock assessment project in 2017-2018. The hosts were examined for parasitic copepods. Collected copepod samples were fixed in 70 % ethanol. Some of them were cleared in lactic acid for a minimum of 24 h. Copepod specimens were dissected out by using Wild M5 and Leica M140 stereo microscopes. All drawings were made with the aid of a drawing tube (Olympus BH-DA). Photos were taken with the aid of a Canon camera (EOS 1100D) connected to the microscope. Identifications and comparisons were performed according to Scott & Scott (1913), Cressey (1967), Hewitt (1967), Kabata (1979) and Kabata (1992). Scientific names, synonyms of parasites, and hosts were checked with WoRMS (2019), Froese & Pauly (2019) and Pollerspöck & Straube (2018).

RESULTS AND DISCUSSION

Female and male samples belonging *Pandarus bicolor* were identified from *Oxynotus centrina* and *Squalus acanthias* (Fig. 1).

Fig. 1. – *Pandarus bicolor* specimens on the anal fins of *Squalus acanthias* (A: 30 cm, B: 5 cm)

Order SIPHONOSTOMATOIDA Thorell, 1859
Family PANDARIDAE Milne Edwards, 1840
Genus *Pandarus* Leach, 1816
Pandarus bicolor Leach, 1816 (Figs 1-10)

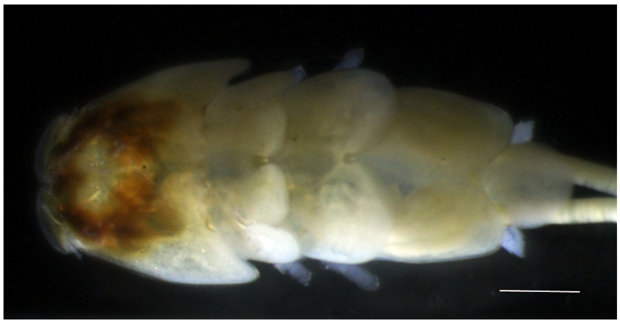

Fig. 2. – Dorsal view of *Pandarus bicolor* ♀ (bar: 1 mm).

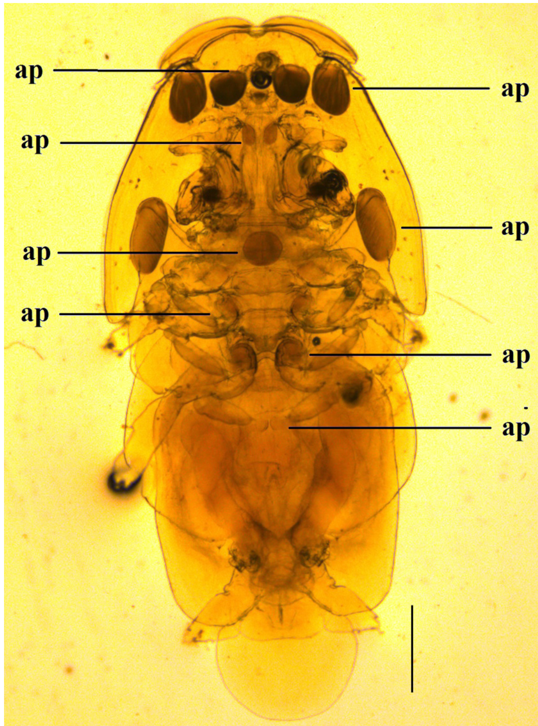

Fig. 3. – Adhesion pads on different places of female body of *Pandarus bicolor* (ap: adhesion pad) (bar: 1 mm).

Female description (Figs 2-7, Table I): Body 6.52 mm (6.2-7 mm excluding egg sac, n = 5). Cephalosome wider 2.56 mm (2.59-2,63) than long 2.42 mm (2.32-2,67). Second thoracic plate wider 2.23 mm (1.98-2.5) than long 0.28 mm (0.25-0.31). Third thoracic plate wider 1.5 mm (1.47-1.55) than long 0.78 mm (0.74-0.89). Fourth thoracic plate wider 2.41 mm (2.3-2.56) than long 1.65 mm (1.39-1.76). Genital complex longer 2.47 mm (2.29-2.66) than width 2.15 mm (2.03-2.34). Abdomen a little longer 1.2 mm (1.1-1.27) than width 1.12 mm (1.06-1.19). Uropod longer 0.45 mm (0.37-0.49) than wide 0.36 mm (0.33-0.39). Egg sac length 7.65 mm (6.96-7.77) 0.31 mm (0.29-0.32) in width (n = 3). Dorsolateral plates of segment 2 not extending beyond the posterior edge of the plate of segment 3. Caudal ramus (Figs 5H, 6L) subtriangular, flattened and pointed distally; armed with three spines on outer margin and two spines on inner margin

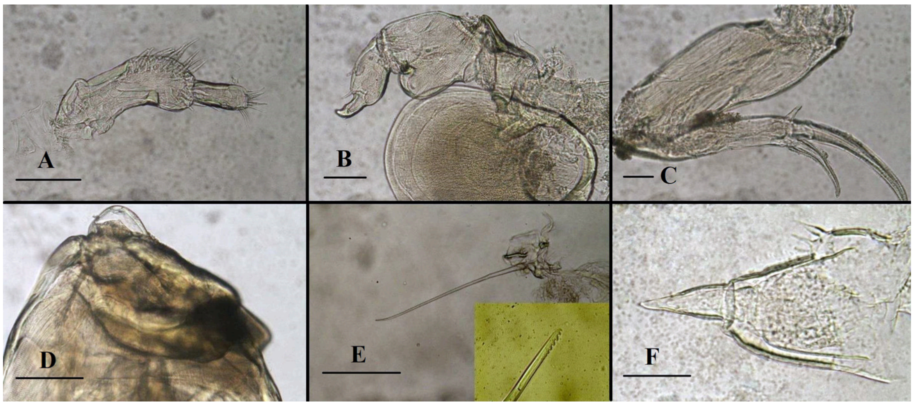

Fig. 4. – *Pandarus bicolor* ♀. **A**: Antennule (bar: 0.17 mm); **B**: Antenna (bar: 0.10 mm); **C**: Maxilla (bar: 0.10 mm); **D**: Maxilliped (bar: 0.16 mm); **E**: Mandible (bar: 0.19 mm), **F**: Maxillule (bar: 0.05 mm).

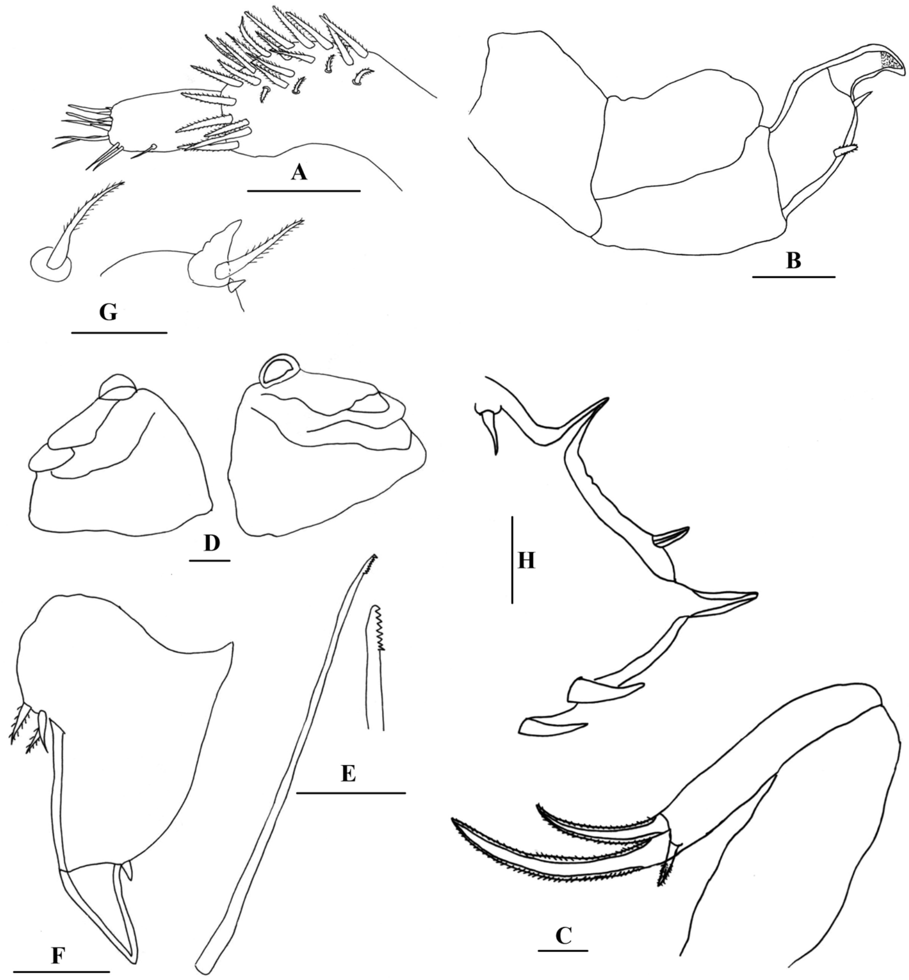

Fig. 5. – *Pandarus bicolor* ♀. **A**: Antennule (bar: 0.17 mm); **B**: Antenna (bar: 0.10 mm); **C**: Maxilla (bar: 0.10 mm); **D**: Maxilliped (bar: 0.16 mm); **E**: Mandible (bar: 0.09 mm); **F**: Maxillule (bar: 0.05 mm); **G**: Fifth leg (bar: 0.05 mm); **H**: Caudal ramus (bar: 0.21 mm).

and one spine on apical. Caudal ramus scarcely visible in dorsal view. Antennule (Figs 4A, 5A) 2-segmented; basal segment broader and longer than distal segment. Basal segment with 24-26 plumose setae; distal segment 5 long setae, five short digitiform setae and three subapical setae. Mandible (Figs 4E, 5E) blade with 8 teeth. Maxilla (Figs 4C, 5C) two-segmented; unarmed lacertus, slender brachium; calamus longer than canna, clavus short. Maxillule (Figs 4F, 5F) bears three setae on palp and a robust process on endite. Antenna (Figs 4B, 5B) three-segmented, first segment with an oval adhesion pad (Fig. 3); second segment slightly longer than first segment, third segment bearing hook-shaped process and with two spines on surface. Maxilliped (Figs 4D, 5D) 2-segmented. Basal segment stout, bearing an adhesion pad. Terminal segment with spatulate tip, without setae. There are several adhesion pads on different places of female body (Fig. 3). Fifth leg (Figs 5G, 6K) bears two plumose setae, one robust and one small seta. Setal and spinal formula of 1-4 legs (Figs 6-7) are as follows (Table II).

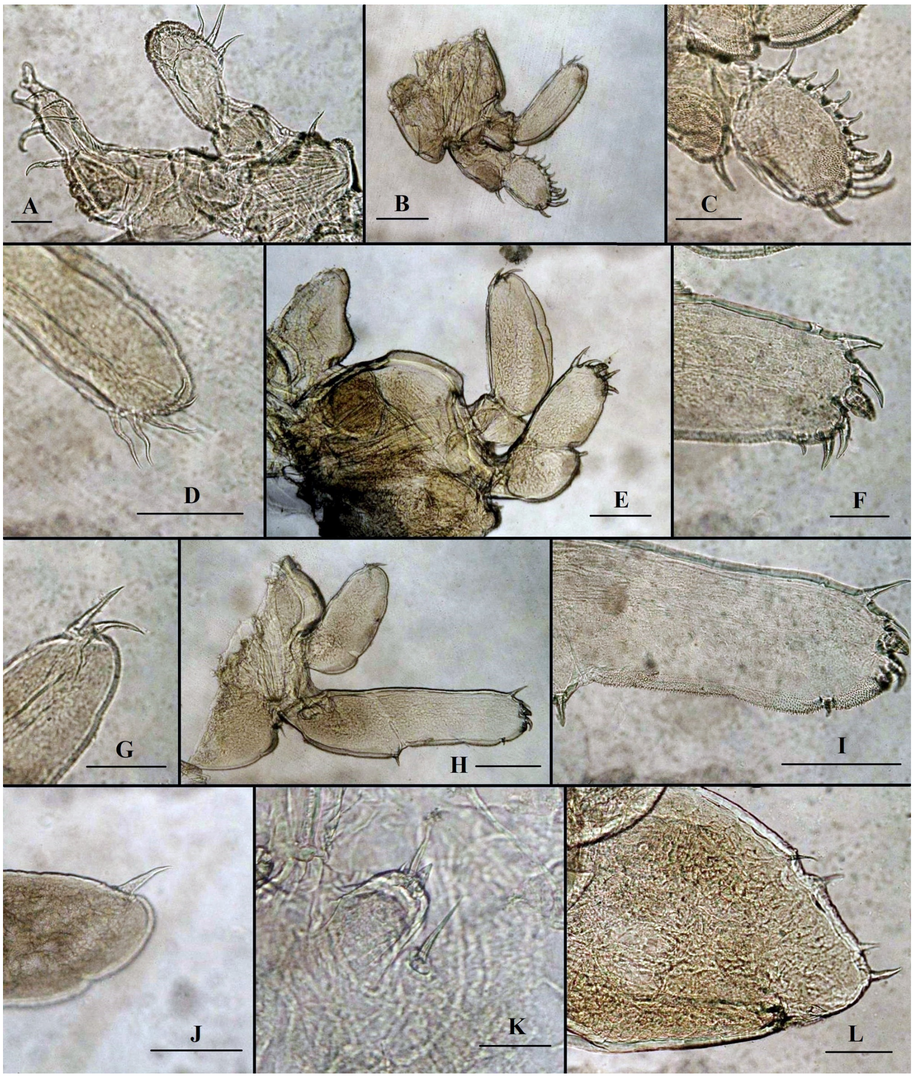

Fig. 6. – *Pandarus bicolor* ♀. **A**: First leg (bar: 0.09 mm); **B**: Second leg (bar: 0.29 mm); **C**: Exopod of second leg (bar: 0.14 mm); **D**: Endopod of second leg (bar: 0.22 mm); **E**: Third leg (bar: 0.25 mm); **F**: Exopod of third leg (bar: 0.12 mm); **G**: Endopod of third leg (bar: 0.20 mm); **H**: Fourth leg (bar: 0.36 mm); **I**: Exopod of fourth leg (bar: 0.26 mm); **J**: Endopod of fourth leg (bar: 0.18 mm); **K**: Fifth leg (bar: 0.05 mm); **L**: Caudal ramus (bar: 0.10 mm).

Table I. – Infestation values and geographical coordinates where hosts species were collected.

Hosts	Coordinates	Examined fish	Infested fish	Prevalence (%)	Mean intensity	Site on host
The angular roughshark, *Oxynotus centrina*	40°39'62"N 27° 23'72"E, 40°40'58"N 28°06'86"E, 40°33'43"N 27°41'28"E	16	4	25	1.25	Body surface, anal, dorsal, and pectoral fins
The picked dogfish, *Squalus acanthias*	40°30'40"N 28°11'32"E, 40°50'21"N 29°03'45"E, 40°39'62"N 27°23'72"E	126	10	7.9	2.9	Body surface, anal, dorsal and pectoral fins

Table II. – Armature of legs 1-4 of adult female of *Pandarus bicolor*.

Legs	Endopod	Exopod
First leg (Figs 6A, 7A)	0-0; 3	3, I, 3; 0-1
Second leg (Figs 6B, 7B)	0-0; 5	0-1; VI-4
Third leg (Figs 6E, 7C)	0-0; 2	0-1; II, 4
Fourth leg (Figs 6H, 7D)	1	1, 1, 3, I

Remarks: This species is characterized by dark brown pigmented areas on the cephalothoracic segment and caudal ramus scarcely visible in the dorsal view. Morphological characters of females from the Sea of Marmara correspond to the description and figures given by Baird (1850), Scott (1900), Wilson (1905), Brian (1906), Scott (1909), Scott & Scott (1913), Barnard (1955), Cressey (1967), Hewitt (1967), Kabata (1979), Asok Kumar (1990) and Kabata (1992).

There are several studies about spinal and setal armature of the female legs of *P. bicolor*. Compared with spinal and setal formulation from these previous studies (Table III), our findings include minor differences in shapes of

Table III. – Comparison of armature of legs 1-4 of adult female of *Pandarus bicolor* in the present work with previous studies (exopod/endopod).

	Scott (1900)	Scott & Scott (1913)	Cressey (1967)	Hewit (1967)	Kabata (1979)	Present study
First leg		4, I; 0-0; 4	1-0; 3, I, 3/ 0-0; 3	1-0; 4, I, 3/ 0-0; 3	1-0; 3, I, 3/ 0-0; 3	1-0; 3, I, 3/ 0-0; 3
Second leg	1-0; VI-2 / 0-0; 5	1-0; V-2/ 0-0; 5	1-0; IV-3/ 0-0; 5	1-0; VI-4/ 0-0; 4	0-1; VI-4/ 0-0; 5	0-1; VI-4/ 0-0; 5
Third leg		1-0; II-2/ 0-0; 2	1-0; II-4/ 0-0; 2	1-0; II-4/ 0-0; 3	0-1; III,3,I/ 0-0; 2	0-1; II, 4/ 0-0; 2
Fourth leg		I, 3,1/ 1	I, 5/1	I, 6/ 1	6/ 1	I, 3, 1, 1/ 1

exopod-endopod and formulation, the only difference being in the number of spines at the second segment of exopod of the third leg and the plumose seta at exopod of fourth leg.

***Male description** (Figs 8-10)*

Host: *O. centrina*

Total number of parasites: 2

Examined fish (*O. centrina*): 16, infested fish: 2, prevalence: 12.5 %, mean intensity: 1

Dissected material: 2

Site on host: body surface and fins

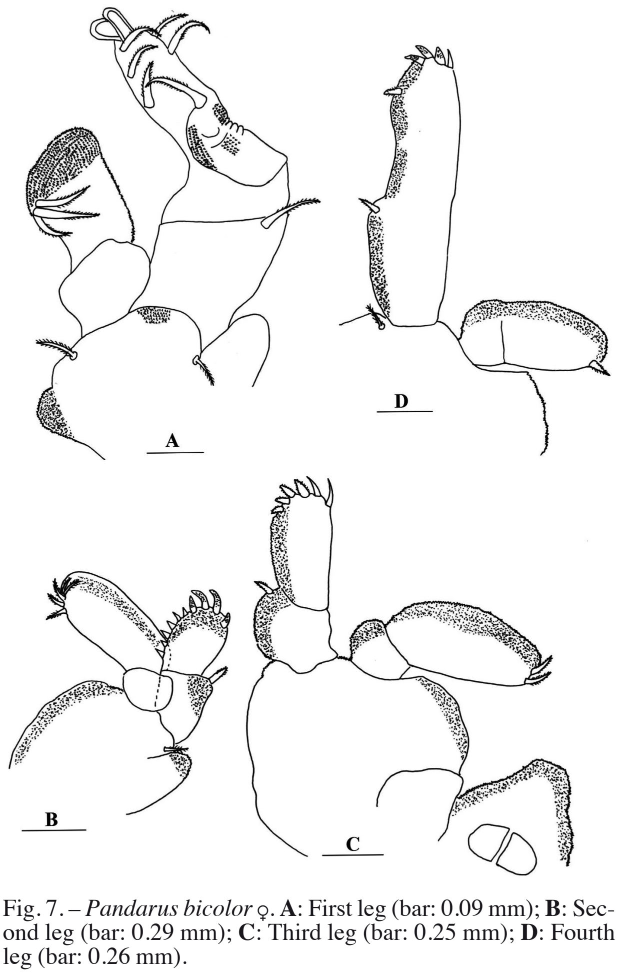

Fig. 7. – *Pandarus bicolor* ♀. **A**: First leg (bar: 0.09 mm); **B**: Second leg (bar: 0.29 mm); **C**: Third leg (bar: 0.25 mm); **D**: Fourth leg (bar: 0.26 mm).

Locality: Sea of Marmara; 40°39'62"N 27°23'72"E for *O. centrina*

Male description. – Body 3.93 mm (3.47-4.3 excluding caudal ramus, n = 2). Dorsal shield wider 1.94 mm (1.91-1.97) than long 1.59 mm (1.54-1.65). Second thoracic plate wider 1.05 mm (1.04-1.06) than long 0.39 mm (0.35-0.43). Third thoracic plate wider 0.91 mm (0.83-0.99) than long 0.35 mm (0.33-0.37). Fourth thoracic plate wider 0.69 mm (0.68-0.70) than long 0.42 mm (0.41-0.44). Genital complex little longer 0.75 mm (0.74-0.75) than width 0.68 mm (0.66-0.69). Abdomen a little wider 0.33 mm (0.31-0.34) than long 0.17 mm (0.16-0.19). Uropod little longer 0.19 mm (0.18-0.20) than wider 0.17 mm (0.16-0.18).

Antennule (Figs 9A, 10A) 2-segmented; basal segment broader and longer than distal segment. Basal segment with 26-27 plumose setae; distal segment 3 subapical long plumose setae, two long plumose setae, three long naked setae, four short setae. Mandible, maxilla, maxillule, antenna (Fig. 10B) as in female. Maxilliped (Figs 9B, 10C) corpus with two small pads on anterior protrusion; subchela without posterior swelling and setae. Caudal ramus (Figs 9C, 10I) bears 2 small and 4 long pinnate setae distally and with medial row of setules. Leg 5 (Figs 9D, 10H) represented by three pinnate setae and one stout seta. Setal and spinal formula of 1-4 legs (Figs 9E-H, 10D-G) are as follows (Table IV).

Remarks. – Males are not pigmented. Kabata (1979) mentioned that the male of this species is not well known, and indicated that there are discrepancies about armature formula of the legs given by various authors. Cressey (1967) mentioned that the male of this species is apparently rare, and gave Scott & Scott (1913)'s armature formula of the legs. We compared the present findings of leg formulation with Scott (1900), Scott (1907), Scott & Scott (1913), Cressey (1967), Hewitt (1967), and Kabata (1979) (Table V). We did not observed a difference among findings for the first leg, and minor difference with the second leg. For example, Scott (1907) and Kabata (1979) gave five plumose setae as seta number at the second segment of second leg exopod; four setae in Hewitt (1967); six setae in Scott (1900), Scott & Scott (1913) as in this study. About the third leg, in the present study we found six setae at the second segment of endopod, which is different from the five setae given by Scott (1907) and Kabata (1979). Concerning the fourth leg, we found four

Fig. 8. – Dorsal view of the male of *Pandarus bicolor.*

plumose setae at the second segment of endopod such as Hewitt (1967) and Kabata (1979), which is different from the five setae given by Scott (1907) and Scott & Scott (1913). Kabata (1979) explained this situation as *Pandarus* undergoes considerable morphological changes in the course of its ontogeny. Benz (1993) indicated that a high degree of variation in both leg segmentation and leg armament exists within Pandaridae.

Table IV. – Armature of legs 1-4 of adult male of *Pandarus bicolor.*

Legs	Endopod	Exopod
First leg (Figs 8E, 9D)	0-0; 3	I-0; IV-3
Second leg (Figs 8F, 9E)	1-0; 8	I-1; IV-5
Third leg (Figs 8G, 9F)	1-0; 5	I-1; IV-5
Fourth leg (Figs 8H, 9G)	1-0; 4	I-1; IV-5

Female and male samples were identified as *P. bicolor*, and we did not observe an important difference between our samples and the morphological descriptions in literature.

Pandarus bicolor has been reported in the Mediterranean Sea (Richiardi 1880, Brian 1906), Atlantic Ocean (Leach 1816, Baird 1850, Bassett-Smith 1899, Scott 1900, Wilson 1907, Wilson 1932, Barnard 1948, Nuñes-Ruivo 1956, Bresciani & Lützen 1962, Cressey 1967), Pacific Ocean (Heegaard 1962), and Indian Ocean (Barnard 1955) (Fig. 11). This pandarid species has mainly been found as a parasite of Elasmobranchii except for *Mola mola* (Actinopterygii) (Dollfus 1946). Kabata (1979) interpreted Dollfus (1946)'s single finding of *P. bicolor* on *Mola mola* as accidental. Nineteen host fish species for *P. bicolor* are listed according to the present literature (Table VI).

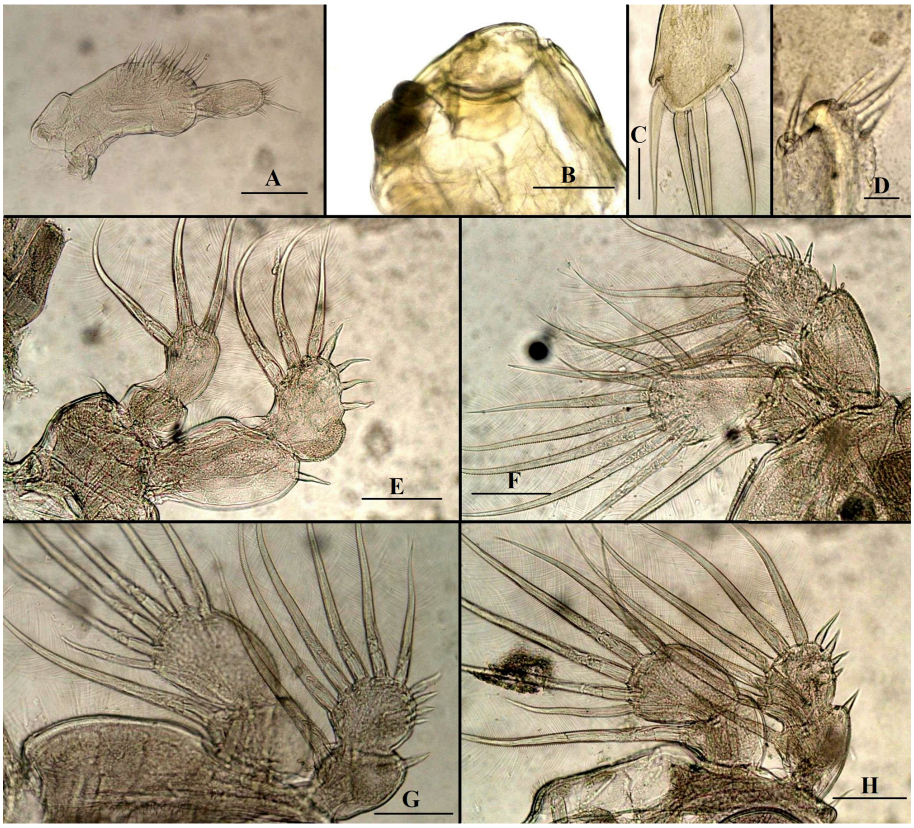

Fig. 9. – *Pandarus bicolor* ♂. **A**: Antennule (bar: 0.17 mm); **B**: Maxilliped (bar: 0.20 mm); **C**: Caudal ramus (bar: 0.17 mm); **D**: Fifth leg (bar: 0.04 mm); **E**: First leg (bar: 0.12 mm); **F**: Second leg (bar: 0.16 mm); **G**: Third leg (bar: 0.15 mm); **H**: Fourth leg (bar: 0.14 mm).

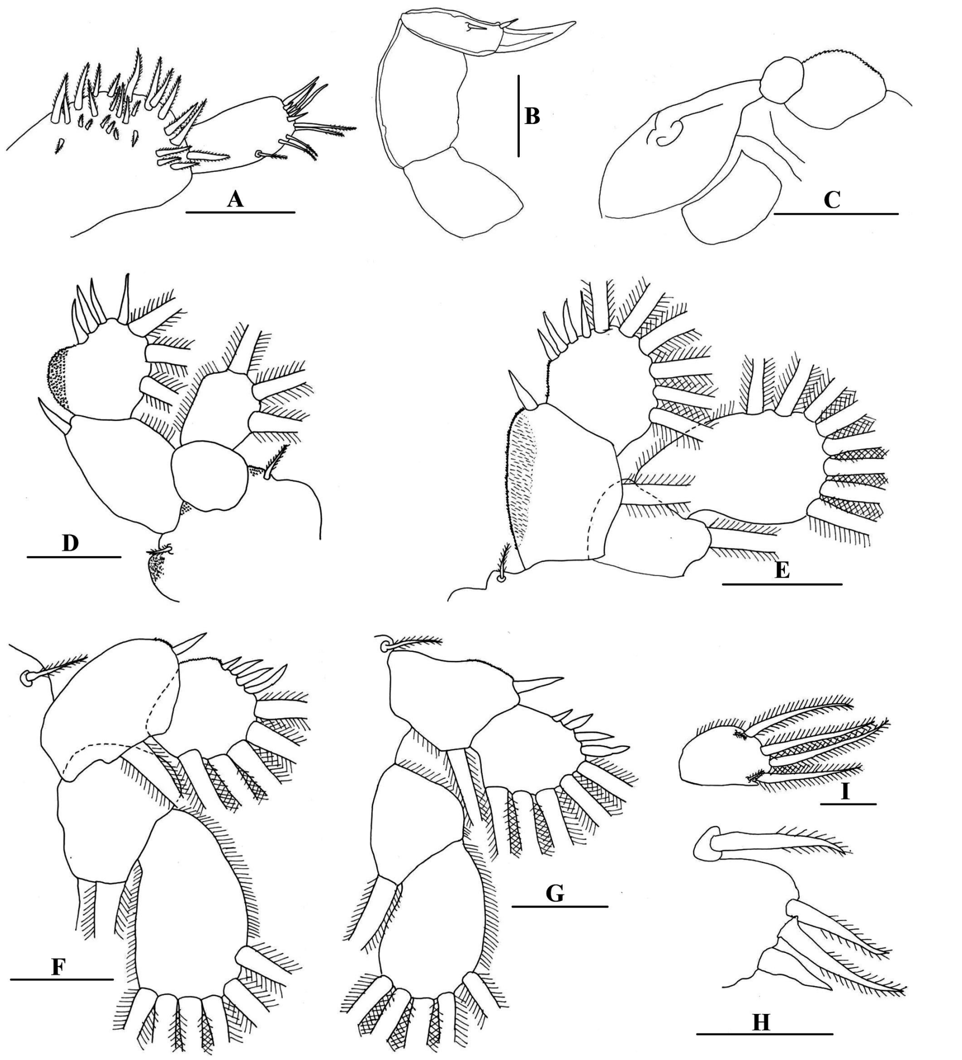

Fig. 10. – *Pandarus bicolor* ♂.
A: Antennule (bar: 0.17 mm);
B: Antenna (bar: 0.18 mm);
C: Maxilliped (bar: 0.20 mm);
D: First leg (bar: 0.12 mm);
E: Second leg (bar: 0.16 mm);
F: Third leg (bar: 0.15 mm);
G: Fourth leg (bar: 0.14 mm);
H: Fifth leg (bar: 0.08 mm);
I: Caudal ramus (bar: 0.34 mm).

Table V. – Comparison of armature of legs 1-4 of adult male of *Pandarus bicolor* in the present study with other findings (exopod/endopod).

	Scott (1900)	Scott & Scott (1913)	Cressey (1967)	Hewit (1967)	Scott (1907)	Kabata (1979)	Present study
First leg		1-0; IV-3/ 0-0; 3	I-0; IV-3/0-0; 3	1-0; IV-3/ 0-0; 3	1-0; IV-3/ 0-0; 3	I-0; IV-3/ 0-0; 3	I-0; IV-3/ 0-0; 3
Second leg	I-1; IV-6/1-0; 8	I-1; IV-6/ 1-0; 8	I-1; IV-6/ 1-0; 8	I-1; IV-4/ 1-0; 7	I-1; IV-5/ 1-0; 8	I-1; IV-5/ 1-0; 8	I-1; IV-6/ 1-0; 8
Third leg		III-0; IV-6/ 1-0; 5	–	–	IV-0; IV-6/ 1-0; 5	I-1; IV-5/ 1-0; 5	I-1; IV-5/ 1-0; 6
Fourth leg		I-0; IV-6 / 1-0; 5	–	II-4/ 4	1-0; V-5/ 1-0; 5	I-1; IV-5/ 1-0; 4	I-1; IV-5/ 1-0; 4

Pandarids are considered as exclusive parasites of elasmobranchs (Benz 1993). Also, according to literature reported in table 5 and our records, *P. bicolor* seems to have a preferential selection for ground sharks (Carcharhiniformes).

Outside elasmobranchs, *P. bicolor* was only reported from the ocean sunfish, *Mola mola* belonging to the class Actinopterygii. This report might be considered as accidental, however, considering the general host selectivity characteristics of *P. bicolor*, even if ocean sunfish is not an Elasmobranchii, its morphological and ecological characteristics (benthopelagic, large slow-swimming fish with a laterally compressed body with hard skin covered by denticles) may place the ocean sunfish among the preferential hosts of the *Pandarus*.

Common host species of *P. bicolor* exhibit placoid scales, large body with moderate swimming speed, and inhabit subtropical coastal waters. All these aspects suggest a differential presettlement of parasitic species such as *P. bicolor* during their copepodite stages. In fact, it is

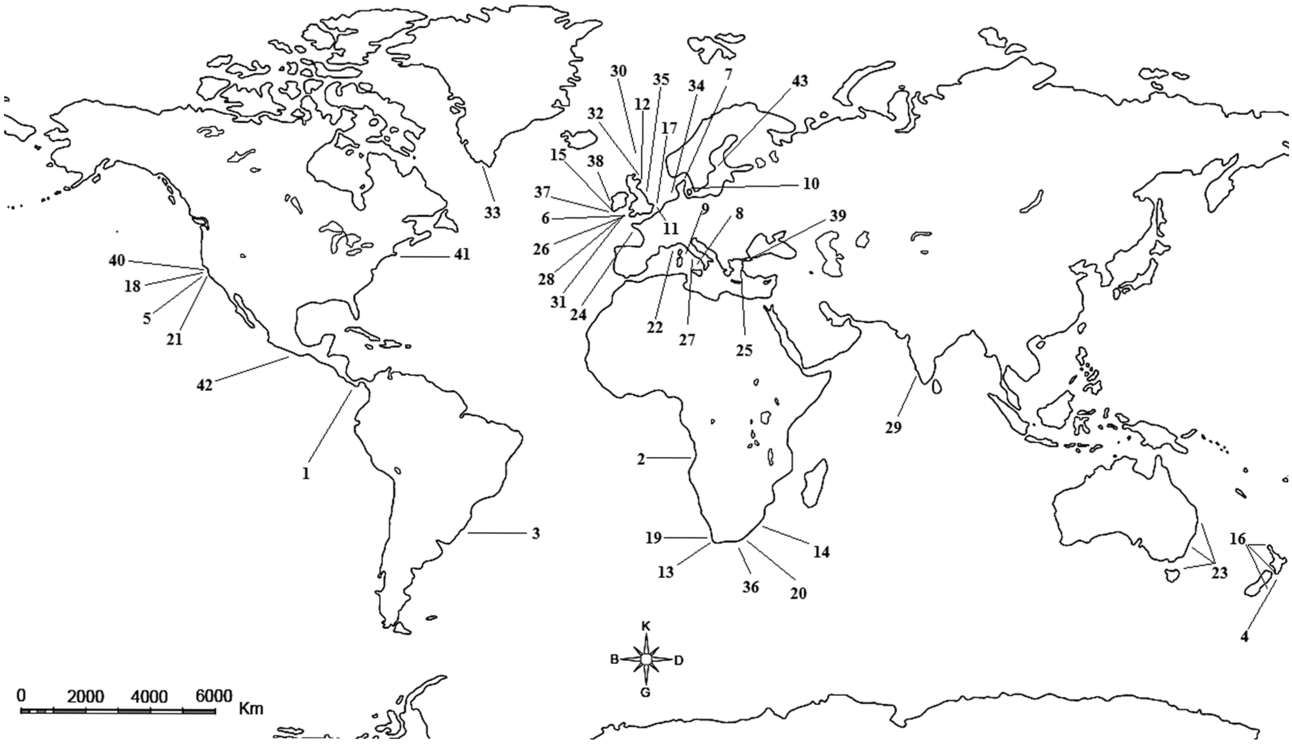

Fig. 11. – Geographic distribution of *Pandarus bicolor* across the World. 1: Boone (1930), 2: Nuñes-Ruivo (1956, 1962), 3: Montú (1996), 4: Hewitt (1979), 5: Benz *et al*. (2003), 6: Leach (1816), 7: Kroyer (1837-1838), 8: Brian (1899), 9: Brian (1906), 10: Kroyer (1846), 11: Van Beneden (1861), 12: Scott (1900), 13: Barnard (1948, 1955), Kensley & Grindley (1973), Kensley & Penrith (1977), 14: Barnard (1955), Kensley & Grindley (1973), Kensley & Penrith (1977), 15: O'Riordan (1966), 16: Hewitt (1967), 17: Hamond (1969), 18: Russo (1975, 2013), 19: Kensley & Grindley (1973), 20: Oldewage & Smale (1993), 21: Ebert (1986a, b; 1989), 22: Brian (1898), 23: Heegaard (1962), 24: Dollfus (1946), 25: Öktener & Trilles (2009), 26: Baird (1850), 27: Richiardi (1880), 28: Bassett-Smith (1896), Leigh-Sharpe (1934), 29: Asok Kumar (1990), 30: Norman (1869), Wilson (1907), 31: Norman & Scott (1906), 32: Scott (1909), 33: Hansen (1923), 34: Cressey (1967), 35: Boxshall (1974), 36: Oldewage (1993), 37: Holmes (1998), 38: Henderson *et al*. (2002), 39: Present study, 40: Wilson (1935), 41: Wilson (1932), 42: Causey (1960), 43: Bresciani & Lützen (1962).

Table VI. –Hosts parasitized by *Pandarus bicolor*

Host Species	English name	Locality	Authors reporting *P. bicolor*
***Galeocerdo cuvier* (Péron & Lesueur, 1822)**	Tiger shark	Jicaron Island, Panama	Boone (1930)
***Carcharhinus falciformis* (Müller & Henle, 1839)** **Syn** *Carcharhinus falciformes* (Müller & Henle, 1839)	Silky shark	Angola	Nuñes-Ruivo (1962) cited by WoRMS (2019)
***Carcharhinus signatus* (Poey, 1868)**	Night shark	Rio Grande do Sul, Southern Brazilian	Montú (1996)
***Carcharodon carcharias* (Linnaeus, 1758)**	Great white shark	Wellington, New Zealand	Hewitt (1979)
		Morro Bay, California	Benz *et al*. (2003)
***Galeorhinus galeus* (Linnaeus, 1758)** **Syn** *Galeorhinus australis* (MacLeay, 1881) *Galeorhinus zyopterus* Jordan & Gilbert, 1883 *Galeus vulgaris* Fleming, 1828 *Galeus canis* Bonaparte, 1834 *Eugaleus galeus* (Linnaeus, 1758) *Squalus galeus* Linnaeus, 1758	Tope shark	Torcross, Devonshire	Leach (1816)
		Northern Kattegat, North Sea	Kroyer (1837-1838) cited by Hewitt (1967)
		Italy	Brian (1899)
		Portoferraio	Brian (1906)
		Copenhagen, Denmark	Kroyer (1846) cited by WoRMS (2019)
		Belgium	Van Beneden (1861)
		Aberdeen Fish Market	Scott (1900)
		False Bay	Barnard (1948)
		Table Bay, False Bay	Barnard (1955)

Table VI. –Continued.

Host Species	English name	Locality	Authors reporting *P. bicolor*
		Valentia Island	O'Riordan (1966)
		Oamaru, Cook Strait, Palliser Bay, Palliser Bay, Cape Turakirae, Makara (New Zealand)	Hewitt (1967)
		Norfolk	Hamond (1969) cited by WoRMS (2019)
		Northern California	Russo (1975)
		False Bay	Kensley & Grindley (1973)
		South-Eastern Cape Recife (South Africa)	Oldewage & Smale (1993)
***Hexanchus griseus* (Bonnaterre, 1788)**	Bluntnose sixgill shark	California Coast	Ebert (1986b)
***Isurus oxyrinchus* (Rafinesque, 1810)** **Syn** *Oxyrrhina spallanzanii* *Isurus mako* Whitley, 1929	Shortfin mako	Liguria	Brian (1898)
		Port Hacking	Heegaard (1962)
***Mola mola* (Linnaeus, 1758)**	Ocean sunfish	Roscoff (Finistère) (France)	Dollfus (1946)
***Mustelus henlei* (Gill, 1863)**	Brown smooth-hound	Northern California	Russo (1975), Russo (2013)
***Mustelus mustelus* (Linnaeus, 1758)** **Syn** *Squalus mustelus* Linnaeus, 1758	Smooth-hound	Torcross, Devonshire	Leach (1816)
		Aegean Sea	Öktener & Trilles (2009)
***Notorynchus cepedianus* (Péron, 1807)** **Syn** *Notorhynchus cepedianus* (Péron, 1807) *Notorhynchus maculatus* Ayres, 1855 *Notorynchus pectorosus* (Garman, 1884)	Broadnose sevengill shark	Oamaru, Raumati Beach (New Zealand)	Hewitt (1967)
		Northern California	Russo (1975)
		Coast of California	Ebert (1986a)
		Coast of California	Ebert (1989)
***Prionace glauca* (Linnaeus, 1758)** **Syn** *Carcharias glaucus* (Linnaeus, 1758)	Blue shark	Falmouth	Baird (1850)
		Italy	Richiardi (1880)
		Collection of British Museum	Bassett-Smith (1899)
***Scyliorhinus stellaris* (Linnaeus, 1758)** **Syn** *Scyllium catulus* Müller & Henle, 1838	Nursehound	Plymouth	Bassett-Smith (1896)
		Collection of British Museum	Bassett-Smith (1899)
***Sphyrna tudes* (Valenciennes, 1822)**	Smalleye hammerhead	Cochin, Kerala Coast	Asok Kumar (1990)
***Squalus acanthias* (Linnaeus, 1758)** **Syn** *Acanthias vulgaris* (Risso, 1827)	Picked dogfish	Shetland Isles	Norman (1869)
		Polperro	Norman & Scott (1906)
		Shetland Isles	Wilson (1907)
		West of Scotland, at the Fish Market in Aberdeen	Scott (1909)
		Faxefjord, West Iceland	Hansen (1923)
		Plymouth	Leigh-Sharpe (1934)
		Oamaru, Kaikoura, Cook Strait, Palliser Bay (New Zealand)	Hewitt (1967)
		North Sea, eastern North Atlantic, off the coast of the Netherlands	Cressey (1967)
		Whitby, Yorkshire, North Sea	Boxshall (1974)
		West coast of South Africa	Oldewage (1993)
		Courtmacsherry Bay, Dingle Bay	Holmes (1998)
		the west coast of Ireland	Henderson *et al.* (2002)

Table VI. –Continued.

Host Species	English name	Locality	Authors reporting *P. bicolor*
		The Sea of Marmara	Present study
***Squalus suckleyi* (Girard, 1855)** **Syn** *Squalus sucklii* (Girard, 1855)	Pacific spiny dogfish	Pacific Grove	Wilson (1935)
***Triakis megalopterus* (Smith, 1839)**	Sharptooth houndshark	Durban, Table Bay	Kensley & Penrith (1977)
***Triakis semifasciata* (Girard, 1855)**	Leopard shark	Northern California	Russo (1975), Russo (2013)
***Oxynotus centrina* (Linnaeus, 1758)**	Angular roughshark	The Sea of Marmara	Present study
Unnamed Hosts and Hosts at genus level			
Unknown shark	Smooth dogfish	Woods Hole	Wilson (1932)
***Carcharias* sp.**	unnamed	Table Bay,	Barnard (1948)
***Carcharias* sp.**	unnamed	Table Bay, False Bay	Barnard (1955)
***Galeorhinus* sp.**	unnamed	Table Bay, False Bay	Barnard (1955)
Unknown shark	Grey shark	Durban	Barnard (1955)
***Carcharhinus* sp.**	unnamed	Angola	Nunes-Ruivo (1956)
***Eulamia* sp.**	unnamed	Coast of Angola	Nunes-Ruivo (1956) cited by Hewitt (1967)
Unknown shark	Flying shark	Acapulco, Guerrero	Causey (1960)
Unknown shark	Unnamed	Lord Howe Island, Port Jackson, New South Wales; Manouard Island, Oyster Bay, Tasmania	Heegaard (1962)
Unknown shark	Unspecified host	Southwest coast of Ireland	O'Riordan (1966)
Unknown shark	Sharks	Swedish waters	Bresciani & Lützen (1962) cited by Hewitt (1967)
***Cyprilumus* sp.**	unnamed	Cook Strait (New Zealand)	Hewitt (1967)
Unknown shark	Grey shark	Karitane (New Zealand)	Hewitt (1967)
Unknown shark	Small shark	West of Cape Brett (New Zealand)	Hewitt (1967)
***Odontaspis* sp.**	unnamed	Table Bay	Kensley & Grindley (1973)
***Carcharhinus* sp.**	unnamed	Durban, Three Anchor Bay	Kensley & Grindley (1973)
Unknown shark	Dogfish	Sea Point	Kensley & Grindley (1973)

well known that environmental factors and host velocity have significant effects during the presettlement of ectoparasites, as reported for *Lepeophtheirus salmonis* (Caligidae: Copepoda) by Genna *et al*. (2005). Benmansour & Ben Hasine (1997), in their comparative analysis of parasitic copepod diversity among coastal fishes of Tunisia, found that benthic fish species had higher parasite richness than pelagic species. Caira & Healy (2004) indicated a high degree of specificity for both skin type and body regions of parasites that attach to elasmobranchs.

Bilecenoğlu *et al*. (2014) indicated the occurrence of 64 species of Elasmobranchii in Turkey. Although there are several studies about the parasites of Actinopterygii in Turkey, not much work has been carried to shed light on the parasitic communities affecting deep sea species.

This preliminary study presents the first occurrence of *P. bicolor*, highlighting its ability to infect also deep sea sharks such as the angular rough shark. More detailed parasitological and histological studies will be considered as further works to improve the knowledge regarding the effects of this parasite on its hosts.

Future research aimed at defining the role of ectoparasites and their ecological effects on deep sea shark species will acquire a pivotal role especially if we consider the changing scenario of the next years, deeply influenced by climate change (*e.g*. global warming). In fact, global climate change produces ecological perturbations, causing geographical and phenological shifts and alteration in the dynamics of parasite transmission, increasing the potential for host switching (Dobson & Carper, 1992). Moreover, the distribution of parasites and pathogens will be directly affected by global warming, but also indirectly, through effects on host range and abundance. In general, transmission rates of parasites and pathogens are expected to increase with increasing temperature (Marcogliese 2008). For these reasons, adding knowledge on parasitic communities of uncommon species and potential changes in host-parasite and disease-vector relationships is of great importance not only from an ecological point of view but also for the management of fishery resources.

Acknowledgement. – The recovered parasites were obtained during a project (TAGEM/HAYSUD/2014/05/01) conducted by the Sheep Research Institute of Ministry of Food, Agriculture, and Livestock of Turkey. The authors wish to thank Prof Furhan Mhaisen for correcting grammar of the manuscript. The first author dedicates this article to Prof Dr G Benz.

REFERENCES

Akmirza A 2016. Check list of the Metazoan Parasites of Fishes Living in the Sea of Marmara. *In* Özsoy, E, Çağatay MN, Balkis N, Öztürk B eds, The Sea of Marmara; Marine Biodiversity, Fisheries, Conservation and Governance. Turkish Marine Research Foundation (TUDAV), Publication N° 42: 710-718.

Alonso MK, Crespo EA, García NA, Pedraza SN, Mariotti PA, Mora NJ 2002. Fishery and ontogenetic driven changes in the diet of the spiny dogfish, *Squalus acanthias*, in Patagonian waters, Argentina. *Environ Biol Fish* 63: 193-202.

Asok Kumar K 1990. Studies on copepod parasites on elasmobranchs of Kerala Coast. PhD Thesis, Department of Industrial Fisheries, Cochin University of Science and Technology, India.

Baird DW 1850. The Natural History of the British Entomostraca. Ray Society, London: 348 p.

Barnard KH 1948. New records and descriptions of new species of parasitic Copepoda from South Africa. *Ann Mag Nat Hist* 12: 242-254.

Barnard KH 1955. South African parasitic Copepoda. *Ann S Afr Mus* 41: 223-312.

Barrull J, Mate I 2001. First confirmed record of angular rough shark *Oxynotus centrina* (Linnaeus, 1758) predation on shark egg case of small-spotted cat shark *Scyliorhinus canicula* (Linnaeus, 1758) in Mediterranean waters. *Ann Ser Hist Nat* 11: 23-28.

Bassett-Smith PW 1896. A list of the parasitic Copepoda of fish obtained at Plymouth. *Mar Biol Ass* 4(2): 155-163.

Bassett-Smith PW 1899. A systematic description of parasitic Copepoda found on fishes, with an enumeration of the known species. *Proc Zool Soc Lond* 67(2): 438-507.

Benmansour B, Ben Hassine OK 1997. Preliminary analysis of parasitic copepod species richness among coastal fishes of Tunisia. *Ital J Zool* 65: 341-344.

Benz GW 1980. Tissue proliferation associated with *Nemesis lamna* Risso, 1826 (Copepoda: Eudactylinidae) infestations on the gill filaments of shortfin makos (*Isurus oxyrinchus* Rafinesque). *J Fish Dis* 3: 443-446.

Benz GW 1993. Evolutionary biology of siphonostomatoida (Copepoda) parasitic on vertebrates. The University of British Columbia, PhD Thesis: 183 p.

Benz GW, Adamson SAM 1990. Disease caused by *Nemesis robusta* (van Beneden, 1851) (Eudactylinidae: Siphonostomatoida: Copepoda) infections on gill filaments of thresher sharks (*Alopias vulpinus* (Bonnaterre, 1758)), with notes on parasite ecology and life history. *Can J Zool* 68: 1180-1186.

Benz GW, Mollet HF, Ebert DA, Davis CR, Van Sommeran SR 2003. Five species of parasitic copepods (Siphonostomatoida: Pandaridae) from the body surface of a white shark captured in Morro Bay. *Calif Pac Sci* 57: 39-43.

Beverley-Burton M, Klassen GJ, Lester RJ 1987. Generic diagnosis of *Asthenocotyle* Robinson, 1961 (Monogenea: Microbothriidae) and description of *Asthenocotyle taranakiensis* new species from *Oxynotus bruniensis* (Oxynotidae) taken in New Zealand waters. *Int J Parasitol* 17: 965-969.

Bilecenoğlu M, Kaya M, Cihangir B, Çiçek E 2014. An updated checklist of the marine fishes of Turkey. *Turk J Zool* 38: 901-929.

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. *Bull Vanderbilt Mar Mus* 3: 221 p.

Borucinska JD, Benz GW 1999. Lesions associated with attachment of the parasitic copepod *Phyllothyreus cornutus* (Pandaridae: Siphonostomatoida) to interbranchial septa of blue sharks. *J Aquat Anim Health* 11: 290-295.

Boxshall GA 1974. Infections with parasitic copepods in North Sea marine fishes. *J Mar Biol Ass UK* 54: 355-372.

Bradai MN, Serena F, Bianchi I, Ebert DA 2007. *Oxynotus centrina*. The IUCN Red List of Threatened Species 2007: e.T63141A12622296.

Bresciani J, Lützen J 1962. Parasitic copepods from the west coast of Sweden, including some new or little known species. *Vidensk Meddel Naturhist Foren* 124: 367-408.

Brian AGG 1898. Note préliminaire sur les copépodes parasites des Poissons. *Bull Inst Oceanogr*, 110: 19 p.

Brian AGG 1899. Crostacei parassiti dei pesci dell'Isola d'Elba (II contribuzione). *Boll Mus Zool Anat Comp R Univ Genova* 4: 1-11.

Brian AGG 1906. Copepodi parassiti dei Pesci d'Italia. Stab. Tipo-Litografico R. Istituto Sordomuti, Genova: 187 p.

Caira JN, Healy CJ 2004. Elasmobranchs as hosts of metazoan parasites. *In* Carrier JC, Musick JA, Heithaus MR eds, Biology of Sharks and their Relatives. Boca Raton, Florida: 523-551.

Capapé C 2008. Diet of the angular rough shark *Oxynotus centrina* (Chondrichthyes: Oxynotidae) off the Languedocian coast (southern France, north-western Mediterranean). *Vie Milieu* 58(1): 57-61.

Capapé C, Seck AA, Quignard JP 1999. Observations on the reproductive biology of the angular rough shark, *Oxynotus centrina* (Oxynotidae). *Cybium* 23: 259-271.

Causey D 1960. Parasitic copepoda from Mexican coastal fishes. *Biol Mar Sci* 10: 323-337.

Cressey RF 1967. Revision of the family Pandaridae (Copepoda: Caligoida). *Proc USA Natl Mus* 121: 1-133.

Dobson A, Carper R 1992. Global warming and potential changes in host-parasite and disease-vector relationships. I: Global warming and biological diversity. Peters RL, Lovejoy TE, eds, New Haven, CT, Yale University Press: 201-217.

Dollfus RP 1946. Essai de catalogue des parasites Poisson-lune *Mola mola* (L. 1758) et autres Molidae. *Ann Soc Sci Nat Charente-Marit* 3: 69-76.

Dragicevic B, Dulcic J, Capapé C 2009. Capture of a rare shark, *Oxynotus centrina* (Chondrichthyes: Oxynotidae) in the eastern Adriatic Sea. *J Appl Ichthyol* 25: 56-59.

Ebert DA 1986a. Biological aspects of the sixgill shark, *Hexanchus griseus*. *Copeia* 1: 131-135.

Ebert DA 1986b. Aspects on the biology of hexanchoid sharks along the California coast. *In* Uyeno T, Arai R, Taniuchi T, Matsuura K eds, Indo-Pacific Fish Biology: Proceedings of the Second International Conference on Indo-Pacific Fishes. Tokyo: Ichthyology Society of Japan: 437-449

Ebert DA 1989. Life history of the sevengill shark, *Notorynchus cepedianus* Peron, in two northern California bays. *Calif Fish Game* 75: 102-112.

Froese R, Pauly D Eds 2019. FishBase. World Wide Web electronic publication. www.fishbase.org, version. (Accessed 2019-06-21).

Genna RL, Mordue W, Pike AW, Mordue AJ 2005. Light intensity, salinity, and host velocity influence presettlement intensity and distribution on hosts by copepodids of sea lice, *Lepeophtheirus salmonis*. *Can J Fish Aquat Sci* 62(12): 2675-2682.

Gerin R, Poulain RM, Beşiktepe Ş, Zanasca P 2013. On the surface circulation of the Marmara Sea as deduced from drifters. *Turk J Earth Sci* 22: 919-930.

Hamond R 1969. The copepods parasitic on Norfolk marine fishes. *Trans Norfolk Norwich Nat Soc* 21: 229-243.

Hansen HJ 1923. Crustacea Copepoda, 2. *In* Copepoda Parasitica and Hemiparasitica. *Danish Ingolf-Exped* 3(7): 1-92.

Heegaard P 1962. Parasitic Copepoda from Australian waters. *Rec Aust Mus* 25: 149-233.

Henderson AC, Flannery K, Dunne J 2002. An investigation into the metazoan parasites of the spiny dogfish (*Squalus acanthias* L.), off the west coast of Ireland. *J Nat Hist* 36: 1747-1760.

Hewitt GC 1967. Some New Zealand parasitic Copepoda of the family Pandaridae. *N Z J Mar Freshw Res* 1(2): 180-264.

Hewitt GC 1979. Eight species of parasitic Copepoda on a white shark. *N Z J Mar Freshw Res* 13(1): 171.

Holmes JMC 1998. A checklist of the Siphonostomatoida (Crustacea: Copepoda) of Ireland. *Bull Irish Biogeogr Soc Dublin* 22: 194-228.

IUCN 2018. The IUCN Red List of Threatened Species. Version 2018-2. http://www.iucnredlist.org. Downloaded on 09 October 2018.

Kabasakal H 2009. Observations on a rare shark, *Oxynotus centrina* (Chondrichthyes: Oxynotidae), in the Sea of Marmara (North-western Turkey). *Pan-Am J Aquat Sci* 4: 609-612.

Kabata Z 1979. Parasitic Copepoda of the British Fishes. The Ray Society Publications, The Bristish Museum, London: 468 p.

Kabata Z 1988. Copepoda and Branchiura. *In* Margolis L, Kabata Z eds, Guide to the Parasites of Fishes of Canada. Part II – Crustacea. *Can Spec Publ Fish Aquat Sci* 101: 3-127.

Kabata Z 1992. Copepods parasitic on fishes. Synopses of the British fauna, New Series. Edited by Kermack DM, SK Barnes & JH Crothers 47: 1-264.

Kensley B, Grindley JR 1973. South African Parasitic Copepoda. *Ann S Afr Mus* 62: 69-130.

Kensley B, Penrith MJ 1977. Biological survey of Sandvis 1: Introduction and faunal list. *Madoqua* 10: 181-190.

Kiliç H 1999. Site selection. The case of Turkey. *CIHEAM-Options Medit* 43: 25-33.

Kroyer H 1837-1838. Om snyltekrebsene, især med Hensyn til den Danske Fauna. III. Formbeskrivelser (Forstsaettelse). *Naturh Tidsskr* 2: 8-52.

Kroyer H 1846. Danmarks Fiske. Copenhagen (Kjobenhavn) 3(1):1-704, figs (1846-1849); 3(2): 705-1279.

Leach WE 1816. Crustaceology: Suppl Annulosa. *In* Edinburgh Encyclopedia: 401-453, pls. 20-26.

Leigh-SharpeWH 1934. A third list of parasitic Copepoda of Plymouth with notes. *Parasitology* 26(1): 112-113.

Marcogliese DJ 2008. The impact of climate change on the parasites and infectious diseases of aquatic animals. *Rev Sci Tech* 27(2): 467-484.

Megalofonou P, Dalamas D 2004. Morphological and biological characteristics of a gravid angular rough shark (*Oxynotus centrina*) and its embryos from the eastern Mediterranean Sea. *Cybium* 28: 105-110.

Menni R, Lopez HL 1984. Distributional patterns of Argentine marine fishes. *Physis Sec A* 42: 71-85.

Montú MA 1996. Records of parasitic copepods of sharks from the southwestern Atlantic. *Nauplius* 4: 179-180.

Norman AM 1869. Last report on dredging among the Shetland Isles. Part 2. On the Crustacea, Tunicata, Polyzoa, Echinodermata, Actinozoa, Hydrozoa, and Porifera. *In* Report of the thirty-eighth meeting of the British Association for the Advancement of Science; held in Norwich in August 1868. London 1869: 247-336.

Norman AM, Scott T 1906. Crustacea of Devon and Cornwall. London: William Wesley and Son: 232 p.

Nuñes-Ruivo L 1956. Copepodes parasitas de peixes dos mares de Angola. *Anais Jta Invest Ultramar* 9: 7-45.

Nuñes-Ruivo L 1962. Copépodes parasites de Poissons des côtes d'Angola (2e série). *Anais Jta Invest Ultramar* 2: 67-86.

Oldewage WH 1993. Occurrence and distribution of copepod fish parasites on the west coast of South Africa. *J Afr Zool* 107: 413-418.

Oldewage WH, Smale MJ 1993. Occurrence of piscine parasitic copepods (Crustacea) on sharks taken mainly off Cape Recife, South Africa. *Afr J Mar Sci* 13: 309-312.

O'Riordan CE 1966. Parasitic copepods in the collections of the National Museum of Ireland. *Proc R Ir Acad B* 64: 371-378.

Öktener A, Trilles JP 2009. Four parasitic copepods on marine fish (Teleostei and Chondrichthyes) from Turkey. *Acta Adriat* 50: 121-128.

Pollerspöck J, Straube N 2018. www.shark-references.com, World Wide Web electronic publication, Version 2018 (Accessed 2019-06-21).

Richiardi S 1880. Contribution alia fauna d'Italia: catalogo sistematico dei crostacei che vivono sul corpo degli animali aquatici. *In* Catalogo degli Espositori: 147-152.

Russo RA 1975. Notes on the external parasites of California inshore sharks. *Calif Fish Game* 61: 228-232.

Russo RA 2013. Observations on the ectoparasites of elasmobranchs in San Francisco Bay, California. *Calif Fish Game* 99: 233-236.

Scott T 1900. Notes on some crustacean parasites of fishes. Part III. Scientific Investigations-Eighteenth Annual Report of the Fishery Board for Scotland. Printed for Her Majesty's Stationery Office, Press, St. Vincent Place: 144-189.

Scott T 1907. Some additional notes on Copepoda from the Scottish seas. *Rep Fish Bd Scotl* 25: 209-220.

Scott T 1909. Some notes on fish parasites. *Rep Fish Bd Scotl* 26: 73-92.

Scott T, Scott A 1913. The British parasitic Copepoda. Ray Society, London, Volumes I and II: 257 p.

Serena F 2005. Field identification guide to the sharks and rays of the Mediterranean and Black Seas. FAO Species Identification Guide for Fishery Purposes. FAO, Rome: 97 p.

Van Beneden PJ 1861. Recherches sur les crustacés du littoral de Belgique. *Bull Belg* ser 2, 1(3): 174 p.

Walter TC, Boxshall G 2019. World of copepods database. Pandaridae Milne Edwards, 1840. http://www.marinespecies.org/aphia.php?p=taxdetails&id=135531 (Accessed 2019-07-31).

Whittington ID, Kearn GC 2011. A new species of *Dermopristis* Kearn, Whittington & Evans-Gowing, 2010 (Monogenea: Microbothriidae), with observations on associations between the gut diverticula and reproductive system and on the presence of denticles in the nasal fossae of the host *Glaucostegus typus* (Bennett) (Elasmobranchii: Rhinobatidae). *Syst Parasitol* 80: 41-51.

Wilson CB 1905. North American parasitic copepods belonging to the family Caligidae, Part I – The Caliginae. *Proc USA Nat Mus* 28: 479-672.

Wilson CB 1907. North American parasitic copepods belonging to the family Caligidae. Parts 3 and 4 – A revision of the Pandarinae and the Cecropinae. *Proc USA Nat Mus* 33: 223-490.

Wilson CB 1932. The copepods of the Woods Hole region, Massachusetts. *Bull US Natl Mus* 158: 1-635.

Wilson CB 1935. Parasitic copepods from the Pacific coast. *Am Midl Nat* 16: 776-797.

WoRMS 2019. World Register of Marine Species. Available from http://www.marinespecies.org at VLIZ. (Accessed 2019-06-21).

Received on December 9, 2019
Accepted on May 29, 2020
Associate editor: Y Desdevises