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Abstract *Microcotyle omanae* n. sp. (Monogenea: Microcotylidae) is described from the gills of *Cheimerius nufar* (Valenciennes) (Sparidae) from the Arabian Sea. The new species closely resembles *Microcotyle arripis* Sandars, 1945, *M. helotes* Sandars, 1944, *M. caudata* Goto, 1984 and *M. sebastis* Goto, 1984, which have also been found in the Indo-Pacific. *Microcotyle omanae* n. sp. differs from *M. arripis*, *M. helotes* and *M. caudata* by its greater number of testes, from *M. arripis*, *M. helotes* by its greater length of the genital atrium, length/width ratio of the genital atrium and length of the eggs, and from *M. helotes* also in greater width of the clamps, from *M. caudata* and *M. sebastis* in its greater number of clamps and additionally from *M. sebastis* by its smaller genital atrial spines and clamps and by the ratio between length and width of the genital atrium. Moreover, the mature specimens of the new species have greater average body length than all above mentioned species. Correlations between 15 morphometric characters and body length are analysed in the new species, and their significance for species differentiation is discussed.

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Introduction

In the Arabian Sea, the sparid fish fauna comprises 16 species belonging to nine genera (Al-Abdessalaam 1995; Randall, 1995). Among them, the santer seabream *Cheimerius nufar* (Valenciennes) is one of the most popular commercial fishes in the region, and its great commercial value makes it an attractive for proposition for aquaculture. In the Aquaculture Centre of the Ministry of Fisheries and Wealth of Oman, the biotechnology of seabream farming has been developed successfully and approved. It is well known that the effective control of diseases caused by parasites is one of the most important elements of successful aquaculture. In addition, parasites can spread from farmed fish to wild populations and conversely (Mladineo & Maršić-Lučić, 2007; Merella et al., 2009). However, the parasite fauna of wild *C. nufar* in the Arabian Sea has not been studied.

Infections caused by monogeneans constitute one of the most important diseases of cultured fish because of their direct life-cycles (Thoney & Hargis, 1991). There are three monogenean species among the parasites collected from *C. nufar* in the Sea of Oman, and one of these is a new species of the genus *Microcotyle* van Beneden & Hesse, 1863. The

pathology and mortality associated with representatives of this genus in cultured and wild fish have previously been reported (e.g. Paperna & Overstreet, 1981; Sanz, 1992; Cruz E Silva et al., 1997; Kim et al., 2001). Most species of *Microcotyle* (i.e. *c*.30) are found in the Indo-Pacific (Gibson et al., 2005), and three species have recently been described from marine fishes in the Arabian Sea off Pakistan (Hadi & Bilqees, 2010, 2011; Hadi et al., 2011). A new species of *Microcotyle* from the santer seabream *C. nufar* in the coastal waters off Oman is described below.

Materials and methods

Thirteen specimens of the santer seabream, *Cheimerius nufar*, 30–34 cm in total length, were caught in the Arabian Sea off Shuweymiyyah (17°54′N, 55°55′E) and Sharbithat (17°39′N, 56°32′E), and identified using Randall (1995) and Al-Abdessalaam (1995). Some fish were examined fresh, the remaining were frozen immediately upon collection and processed later. Gills were removed, placed in seawater and checked for monogeneans under a Zeiss Stemi 2000-C dissecting microscope. Some of the monogeneans collected were stained with acetocarmine, fixed in 70% ethanol, differentiated in 'iron water' ($H_2O + Fe_2O_3$) and acid alcohol (70% ethanol with 3% HCl), dehydrated using an ethanol series (80–100%), cleared in clove oil and mounted in Canada balsam. Other parasites were stained with Mayer's paracarmine after fixation in 70% ethanol, dehydrated and mounted in Canada balsam (Roskin & Levinson, 1957).

Measurements and light micrographs were made using a Zeiss AxioScope A1 K fitted with an AxioCam Rc digital camera using AxioVision Rel. 4.8.2 (K. Zeiss Application Software) at different magnifications of ×50, ×100, ×200, ×400. The figures were made from a series of photos using the program Inkscape 0.48.2.-1 [2011. Scalable Vector Graphics (SVG) URL: http://www.inkscape.org).

All dimensions are given in micrometres as the mean and standard error, with the range and the number of measurements in parentheses. The length and width of most of organs and other measurements were measured along the longitudinal and transverse axes, respectively; for the buccal organs, testes and clamps, which are arranged at an angle to the axis of the body, the greatest dimension was considered to be the length for the former two and as the width for the latter. For the correlation analysis, the measurements were taken only from adult specimens, their maturation being defined by the complete formation of the genital atrium and gonads. The descriptive statistics and Pearson correlations were calculated using the software package Statistica 6 for Windows.

Museum abbreviations are as follows: British Museum (Natural History) Collection at the Natural History Museum, London (BMNH); Institute of the Southern Seas, Sevastopol, Ukraine (IBSS).

Results

Eighty-nine microcotylids were recovered from examined specimens of *Cheimerius nufar*. Their general morphology (Figs. 1B, 2A) agrees with that described by Mamaev (1989) for *Microcotyle* spp., and all of them belong to a single new species.

Microcotylidae Taschenberg, 1879
Microcotyle van Beneden & Hesse, 1863

Microcotyle omanae n. sp.

Type-host: *Cheimerius nufar* (Valenciennes) (Sparidae), santer seabream.
Type-locality: off Sharbithat (17°39′N, 56°32′E), Arabian Sea.
Other locality: off Shuweymiyyah (17°54′N, 55°55′E), Arabian Sea.
Site on host: Gills.
Type-specimens: 20 specimens: holotype and 9 paratypes deposited in the BMNH collection (holotype: BMNH 2013.8.30.1; paratypes: BMNH 2013.8.30.2-10). Additional paratypes are deposited in the IBSS collection (Reg. No. 524/1-10).
Infection details: Of the five fishes caught off Shuweymiyyah (ix.2012), three were infected by three, eight and nine monogeneans, as were all of the eight fishes caught off Sharbithat (xii.2012–i.2013), which were parasitised by 6–22 (mean 9 ± 2) specimens.

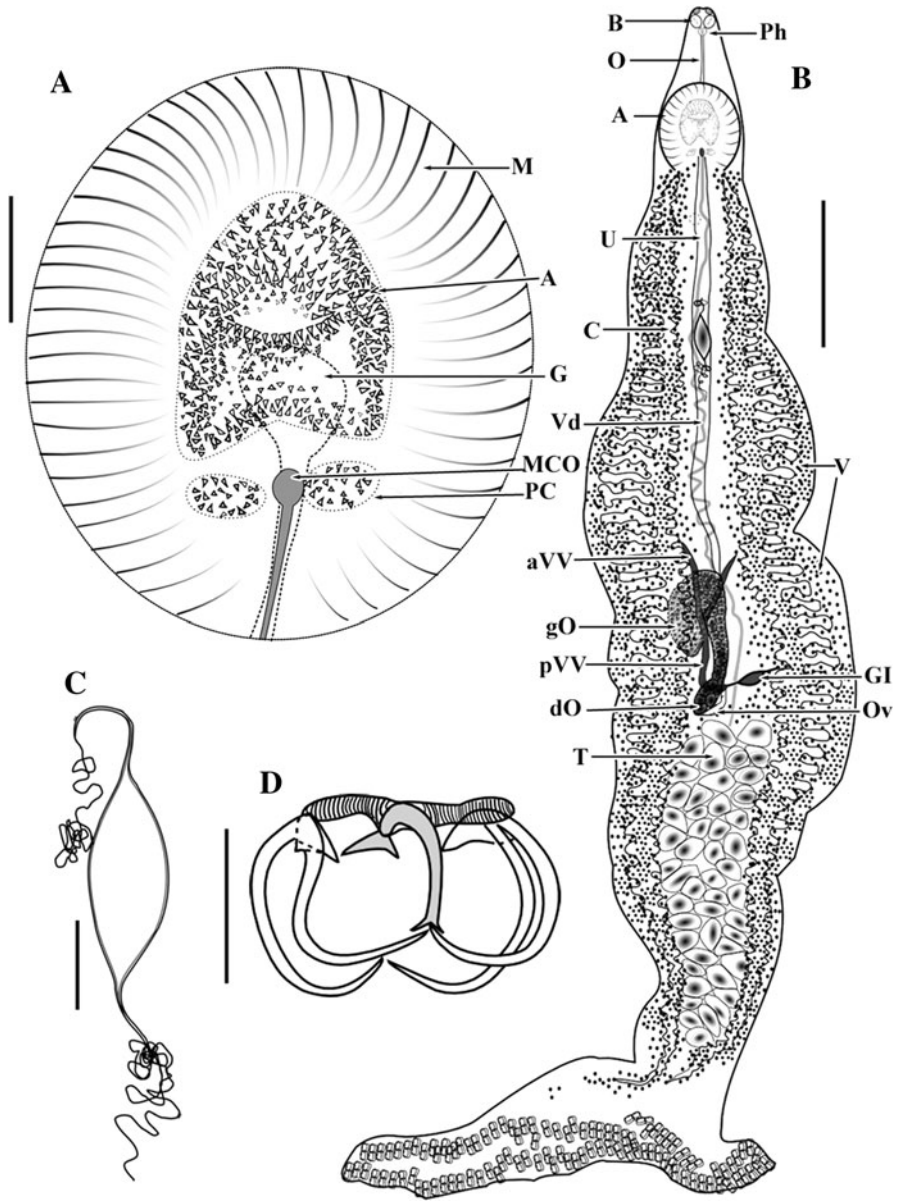

Fig. 1 *Microcotyle omanae* n. sp. from *Cheimerius nufar* in the Arabian Sea. Holotype. A, genital atrium; B, whole-mount (dorsal view); C, egg; D, clamp. *Abbreviations*: A, genital atrium; aVV, anterior branches of the vitello-vaginal duct; B, buccal organs; C, caecum; dO, distal branch of the ovary; G, gonopore; GI, genito-intestinal canal; gO, germinal branch of the ovary; M, radial musculature of the genital atrium; MCO, male copulatory organ; O, oesophagus; Ov, oviduct; PC, posterolateral cavities of the atrium; pVV, posterior branches of the vitello-vaginal duct; T, testes; V, vitellarium; Vd, vas deferens; U, uterus. *Scale-bars*: A, C, 100 μm; B, 1,000 μm; D, 50 μm

Etymology: The species name refers to the Sultanate of Oman, in coastal water of which this monogenean was found.

Description (Figs. 1–2)

Body fusiform, elongate (Figs. 1B, 2A, E); total length of adult specimens 6,020 ± 420 (3,500–11,000; $n = 15$) and of juveniles 1,475 ± 162 (1,150–1,950; $n = 5$); width at ovary 910 ± 90 (475–1,875) and 229 ± 24 (150–300), respectively. Body passes smoothly into subsymmetrical haptor, which occupies 33 ± 2 (19–57)% of total body length and is 1,908 ± 170 (1,125–3,225) long in adults and 547 ± 54 (435–700) in juveniles. Haptor armed with

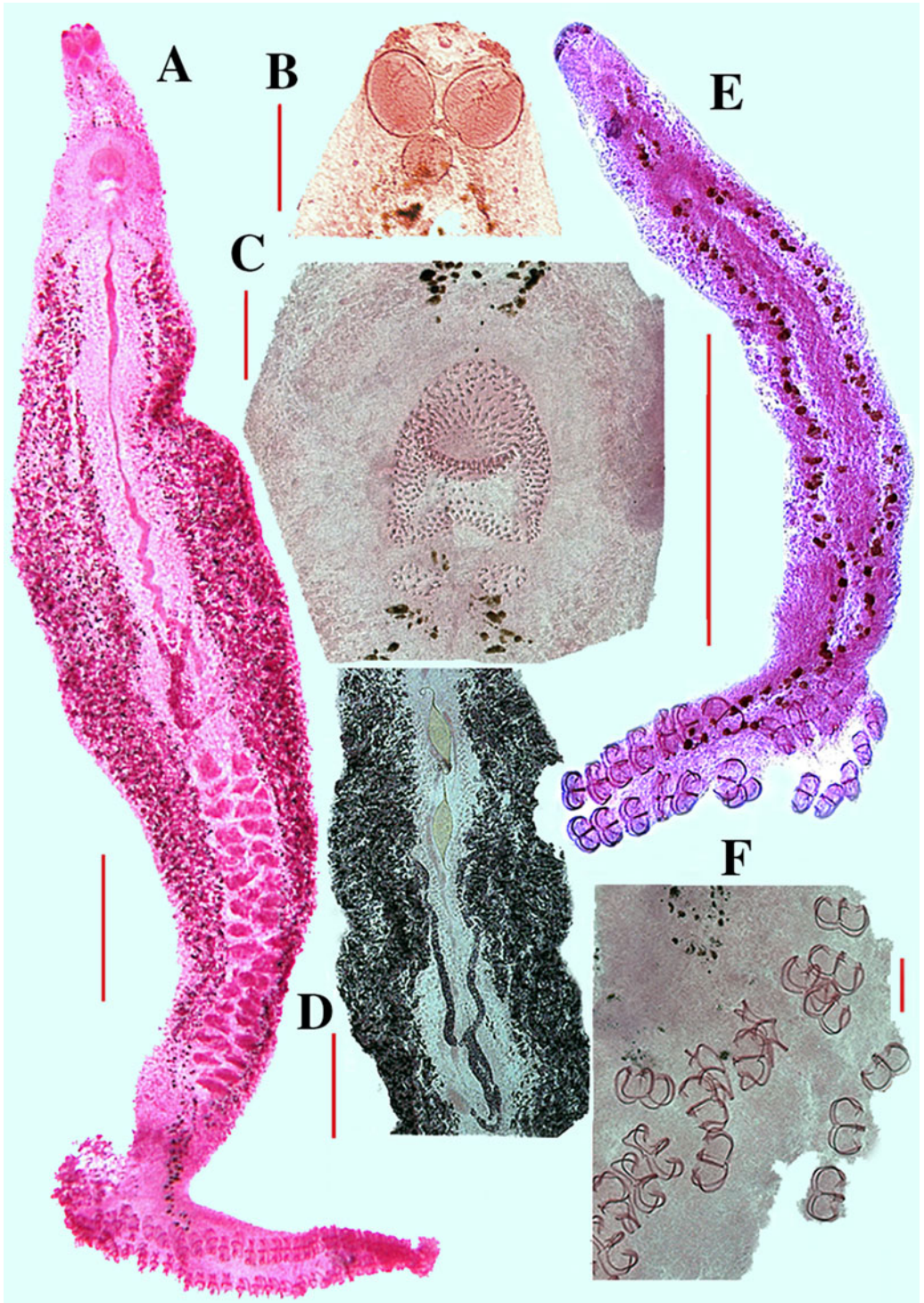

Fig. 2 Photomicrographs of *Microcotyle omanae* n. sp. from *Cheimerius nufar* in the Arabian Sea. A, whole-mount of a paratype (adult specimen), dorsal view; B, paratype, anterior end of body with buccal organs and pharynx; C, holotype, genital atrium; D, paratype, middle part of body with vitello-vaginal duct and eggs; E, whole-mount of a paratype (juvenile specimen); F, clamps. *Scale-bars*: A, 1000 μm; B, C, F, 100 μm; D, E, 500 μm

110 ± 2 (94–120; $n = 20$) and 32 ± 4 (24–45) clamps in adults and juveniles, respectively. Clamps of *Microcotyle*-type (Figs. 1D, 2F), densely arranged in 2 equal ventrolateral rows, 44 ± 2 (26–55) × 84 ± 2 (70–100) in adults and 38 ± 2 (33–43) × 65 ± 4 (55–80) in juveniles; clamps largest in centre of haptor.

Pair of oval septal buccal organs (Fig. 2B) 89 ± 4 (60–120) × 65 ± 4 (40–95) in adults and 49 ± 4 (43–65) × 37 ± 3 (33–48) in juveniles. Prepharynx absent; pharynx subcircular, 50 ± 3 (28–75) long in adults and 43 ± 5 (30–55) long in juveniles. Ratio of length of buccal organs/length of pharynx 1.8 ± 0.06 (1.3–2.2). Oesophagus 531 ± 60 (290–1,250) long, without lateral diverticula. Intestine bifurcates at level of genital atrium. Caeca with lateral and medial diverticula, not united posteriorly; left caecum extends into haptor.

Testes 44 ± 1 (34–55; $n = 22$) in number, irregular in shape and size, 141 ± 10 (100–220) × 72 ± 6 (50–120), generally occurring in 2–4 interleaved rows (Figs. 1B, 2A), intercaecal, in posterior half of body proper. Vas deferens conspicuous, coiled anteriorly in mid-line, ends with unarmed bulbous male copulatory organ 25–26 ($n = 3$) in diameter which opens into posterior part of genital atrium (Figs. 1A, 2C). Prostatic glands absent. Genital atrium located at 2,506 ± 190 (1,625–4,800) from anterior end of body, large, with well-developed radial musculature. Genital atrium proper inverted heart-shaped (Figs. 1A, 2C), 170 ± 7 (125–214) long and 150 ± 6 (127–193) wide; length/width ratio very stable, 1.2 ± 0.02 (1.1–1.3). Two additional posterior cavities ("pockets" of Mamaev, 1989) of atrium, 50 ± 2 (35–72) × 30 ± 3 (21–64), arranged symmetrically laterally to male copulatory organ (Figs. 1A, 2C). Outer edges of atrium and its inner walls armed with numerous conical spines; posterolateral "pockets" with 22–24 spines, 8 ± 0.5 (6–10) long ($n = 30$) (Figs. 1A, 2C).

Ovary in form of question-mark (Figs. 1B, 2A), anterior to testes, located at 2,506 ± 190 (1,625–4,800) from anterior extremity of body. Left (germinal) ovarian branch 338 ± 30 (225–480; $n = 10$) long; right (distal) branch 439 ± 40 (260–850; $n = 14$) long. Oviduct arises from right ovarian branch (Fig. 1B). Uterus extends anteriorly and medially towards genital atrium. Genito-intestinal canal unites right caecum with oviduct. Vagina, vaginal pore and Mehlis' gland not observed. Vitellarium follicular, located around intestinal diverticula, extends from level of intestinal bifurcation to haptor, with some follicles being found in haptor and anteriorly to genital atrium. Two vitello-vaginal ducts, 374 ± 20 (250–600) long, unite posteriorly to form common duct, 476 ± 40 (200–780) long, i.e. forming Y-shaped structure (Figs. 1B, 2D). Eggs fusiform (Fig. 1C), 289 ± 5 (260–300; $n = 9$) long, 86 ± 3 (75–105; $n = 9$) wide, with 2 long filaments bearing strongly curled tips.

Differential diagnosis

Microcotyle omanae n. sp. most closely resembles *M. arripis* Sandars, 1945 which has been described from *Arripis georgianus* (Valenciennes) in the Indian Ocean off Australia (Sandars, 1945; Dillon et al., 1984; Williams, 1991; Catalano et al., 2010) and also found on *Scolopsis vosmeri* (Bloch) and *S. taenioptera* (Cuvier) in the South China Sea (Zhang et al., 2001). It is similar in the general shape of the genital atrium with two posteriolateral "pockets", the size and arrangement of the spines, the main proportions of the body (Table 1) and the topology of the organs. The new species differs in: (i) the greater length of the genital atrium; (ii) the shape of the genital atrium, which has a length/width ratio of >1, whereas in *M. arripis* this ratio is <1; (iii) the greater number of testes; and (iv) the greater length of the eggs (Table 1).

Among other species of *Microcotyle* found in the Indo-Pacific region, *M. helotes* Sandars, 1944 appears similar to *M. omanae* n. sp. in the general shape and armament of the genital atrium, the number of the clamps and the ratio of the length of the buccal organs in relation to the length of pharynx (Table 1). *Microcotyle helotes* was described from *Pelates sexlineatus* (Quoy & Gaimard) off Western Australia (Sandars, 1944) and has been redescribed from the same host (Dillon et al., 1984), from *Pelsartia humeralis* (Ogilby) in Australian waters (Williams, 1991) and from *Therapon theraps* Cuvier in the South China Sea (Zhang et al., 2001). The new species can be distinguished from *M. helotes* by its greater: (i) length of the genital atrium; (ii) ratio between its length and width; (iii) number of testes, (iv) width of the clamps; and (v) length of the eggs (Table 1).

Microcotyle caudata Goto, 1894 and *M. sebastis* Goto, 1894, described from *Sebastis* spp. off the coast

Table 1 Comparative metrical data for *Microcotyle omanae* n. sp. and for morphologically closely related species of *Microcotyle* from the Indo-Pacific region

	M. omanae n. sp.	*M. arripis* Sandars, 1945			*M. helotes* Sandars, 1944	*M. caudata* Goto, 1984	*M. sebastis* Goto, 1984
Hosts in the Indo-Pacific	*Cheimerius nufar*	*Arripis georgianus*		*Scolopsis vosmeri*; *S. taenioptera*	*Pelates sexlineatus*; *Pelsartia humeralis*; *Therapon theraps*	*Helicolenus dactylopterus*; *Setarches longiceps*	*Sebastes* spp.
Locality in the Indo-Pacific	AS	off WA	off SA	SCS	off WA, SEIO, SCS	SWIO	ECS, YS
Source	Present study	Sandars (1945)[a]; Dillon et al. (1984)[b]; Williams (1991)[c]	Catalano et al. (2010)	Zhang et al. (2001)	Dillon et al. (1984)[b]; Williams (1991)[c]	MacCallum & MacCallum (1913)[d]; Sandars (1945)[a]; Yamaguti (1963)[e]	MacCallum & MacCallum (1913)[d]; Sandars (1945)[a]; Yamaguti (1963)[e,f]; Radujkovic & Euzet (1989)[g]
Body length	3,500–11,000	2,080[a] 1,684–2,530[b] 4,347[c]	867–2,713	1,780–3,458	1,610–1,730[b] 1,773–3,088[c]	3,200[e]	5,500[e] 2,500–3,200[g]
Haptor length	1,125–3,225	528[a] 707–874[b] 1,287[c]	148–939	786–1,258	610[b] 684–1,160[c]	800[d]	1,100[d]
Number of clamps	94–120	70[a] 68–108[b] 78–96[c]	44–96	47–58	54–60[b] 37–103[c]	32–50[e] 50[d]	52–56[e] 46–62[f] 38–56[g]
Central clamp length	26–55	32[a] 34–45[b] 37–46[c]	9–28	34–52	34–39[b] 33–42[c]	45[a]	68[a]
Central clamp width	70–100	48[a] 56–70[b] 56–66[c]	26–54	49–85	51–55[b] 42–67[c]	80[a]	128[a]
Buccal organ length	60–120	64[a] 37–45[b] 41–49[c]	20–35	39–57	60[b] 46–72[c]	–	40–45[g]
Pharynx length	28–75	48[a] 38–47[b] 46–56[c]	29–40	44–52	35–38[b] 33–46[c]	–	–
Buccal organ/pharynx length ratio	1.3–2.2	0.9–1.3	0.8	≤1	1.5	–	–
AE to GA	315–932	240[a] 177–270[b] 360–441[c]	107–306	–	184[b] 175–246[c]	–	–

Table 1 continued

	M. omanae n. sp.	*M. arripis* Sandars, 1945			*M. helotes* Sandars, 1944	*M. caudata* Goto, 1984	*M. sebastis* Goto, 1984
Hosts in the Indo-Pacific	*Cheimerius nufar*	*Arripis georgianus*		*Scolopsis vosmeri*; *S. taenioptera*	*Pelates sexlineatus*; *Pelsartia humeralis*; *Therapon theraps*	*Helicolenus dactylopterus*; *Setarches longiceps*	*Sebastes* spp.
Locality in the Indo-Pacific	AS	off WA	off SA	SCS	off WA, SEIO, SCS	SWIO	ECS, YS
Source	Present study	Sandars (1945)[a]; Dillon et al. (1984)[b]; Williams (1991)[c]	Catalano et al. (2010)	Zhang et al. (2001)	Dillon et al. (1984)[b]; Williams (1991)[c]	MacCallum & MacCallum (1913)[d]; Sandars (1945)[a]; Yamaguti (1963)[e]	MacCallum & MacCallum (1913)[d]; Sandars (1945)[a]; Yamaguti (1963)[e,f]; Radujkovic & Euzet (1989)[g]
GA length	125–214	80[a] 92–103[c]	21–60	–	72–92[c]	–	170[g]
GA width	127–193	128[a] 164–201[b] 114–137[c]	39–113	–	88[b] 74–116[c]	–	95[g]
GA length/width ratio	1.1–1.3	0.6–0.8	0.5	–	0.8–0.9	–	1.8
GA spine length	6–10	12[a] 10–16[b]	7–10	–	8–10[b]	10[d]	17[d]
Testes number	34–55	23[a] 13–22[b] 17–19[c]	15–21	13–23	12–13[b] 9–19[c]	20–27[e] 23[d]	36–43[e] 21–48[f] 15–17[g]
Egg-length	260–300	224[a] 233–248[b]	99–145	–	234–240[c]	–	–
Egg-width	75–105	80[a] 68–92[b]	22–28	–	74–80[c]	–	–

Abbreviations: AS, Arabian Sea; WA, Western Australia; SA, Southern Australia; SCS, South China Sea; ECS, East China Sea; YS, Yellow Sea; SEIO, Southeast Indian Ocean; SWIO, Southwest Indian Ocean; AE, anterior extremity of body; GA, genital atrium

[a–g] Data correspond to respective sources. Data from: [e] Yamaguti (1963) and [d] Goto (1984: cited by MacCallum & MacCallum, 1913) from the Sea of Japan, [f] Bonham & Guberlet (1937: cited by Yamaguti, 1963) from the NE Pacific Ocean and [g] Radujkovic & Euzet (1989) from the Adriatic Sea, are used for comparison, as data for these species from Indo-Pacific are absent

of Japan (Yamaguti, 1963), and also recorded from the Indian Ocean (Parukhin, 1989) and the South China Sea (Kim et al., 2001), have some similarities with the new species in the shape of the genital atrium. However, *M. omanae* differs from both species in its greater number of clamps. The new species can also be differentiated from *M. caudata* by its greater number of testes and from *M. sebastis* by its smaller genital atrial spines and clamps and by the length/width ratio of the genital atrium (Table 1).

Moreover, the new species has a greater body size than all the above mentioned morphologically closely related congeners (Table 1). Body size on its own is not an adequate diagnostic character, as it can depend on parasite age, host size, environmental factors and even on the degree of flattening of the worms during preparation. However, specimens of *Microcotyle omanae* n. sp., which had a body length of less than 2,000 μm, were all juvenile and the formation of the genital atrium and testes has only just begun in worms of this size (Fig. 2E), and mature specimens had a body length greater than 3,500 μm. Whereas, for example, Sandars (1945), Dillon et al. (1984), and Catalano et al. (2010) not only describe fully-formed reproductive organs but also provide data on the eggs for specimens of *M. arripis* which had an average body length of less than 2,000 μm. Therefore, in our view, it is possible to use the large size of adult specimens of the new species as an additional diagnostic character.

Among the species of *Microcotyle* known from other regions, *M. donavini* van Beneden & Hesse, 1863, *M. erythrini* van Beneden & Hesse, 1863 and *M. fusiformis* Goto, 1894 appear similar to the new species in the shape of the genital atrium. However, *M. omanae* n. sp. differs from all of these species in its greater number of testes (34–55 *vs* 18–22 in *M. donavini,* 16–29 in *M. erythrini* and 15 in *M. fusiformis*). It can be further distinguished from *M. donavini* by the shorter length of the genital atrium (125–214 *vs* 250 μm) and the greater length of the eggs; and from *M. fusiformis* by the greater number of clamps (94–120 *vs* 60–66) (comparative data from Radujkovic & Euzet, 1989 and Yamaguti, 1963).

Correlation analysis

Many comparative characters have greater dimensions in *M. omanae* n. sp. (Table 1). Since these can be correlated with body size, the linear relationships between the 15 most taxonomically significant measurements and body length in 15 mature specimens were analysed using Pearson's correlation coefficient (Table 2). Positive linear dependence on the body length has been revealed only for eight longitudinal measurements. The highest correlation with body length was found for the length of the buccal organs. Characters associated with the distances between parts of the body that determine the position of the organs, as well as the size of the gonads, were also significantly correlated with body length. Most of the characters positively depending on the length of the body were also correlated with each other. Despite the fact that the size of the testes and the length of the testicular field are significantly positively correlated with body length, their number was independent of the latter, as was the number of the clamps and their size. A relationship with body size was also not found for the length of the haptor, pharynx, genital atrium and vitello-vaginal duct.

Discussion

Microcotyle is one of the oldest monogenean genera and has been repeatedly revised (e.g. Yamaguti, 1963; Unnithan, 1971; Mamaev, 1977, 1986; Mamaev & Lebedev, 1979). Many genera have been hived off from it, resulting in dozens of species being transferred to other microcotylid genera (e.g. Tripathi, 1956; Yamaguti, 1963; Unnithan, 1971; Caballero y Caballero & Bravo-Hollis 1972; Mamaev & Egorova, 1977; Mamaev, 1977, 1989; Chisholm et al., 1991) and some of the newly erected genera have been reunited in synonymy with this genus (e.g. Mamaev, 1977). The diagnosis of *Microcotyle* was last amended by Mamaev (1989), who listed 49 species within it; however, he noted that, although they unquestionably belonged to *Microcotyle*, the validity of half of them needs to be confirmed and, indeed, redescribed. So far, most of these species have not been reinvestigated and this complicates the differentiation of any new species.

Another problem that we faced in describing the new species is the great intraspecific variability in practically all metrical characters used for the differentiation of representatives of *Microcotyle* spp. This problem has been discussed previously by others (Thoney & Munroe, 1987; Williams, 1991). Moreover, in contrast to members of many other

Table 2 Coefficients of determination (r^2) for correlations between body length and the longitudinal measurements in *Microcotyle omanae* n. sp. Values corresponding to significant correlations ($p < 0.05$) are given in bold

		Body length	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Buccal sucker length	**0.97**														
2	Pharynx length	0.40	0.36													
3	Oesophagus length	**0.89**	**0.83**	0.28												
4	AE to genital atrium	**0.96**	**0.93**	0.37	**0.95**											
5	Genital atrium length	0.43	0.57	0.04	0.26	0.49										
6	AE to ovary	**0.88**	**0.86**	0.21	**0.95**	**0.93**	0.39									
7	Ovary length	**0.89**	**0.92**	0.09	0.74	**0.84**	0.59	0.73								
8	Vitello-vaginal duct length	0.53	0.46	0.45	0.50	0.57	0.33	0.59	0.19							
9	AE to testes	**0.90**	**0.89**	0.34	**0.95**	**0.94**	0.38	**0.99**	0.72	0.62						
10	Testicular field length	**0.87**	**0.83**	0.05	**0.89**	**0.90**	0.45	**0.89**	**0.87**	0.42	**0.84**					
11	Testes length	**0.80**	**0.81**	0.47	**0.76**	**0.88**	0.62	0.69	**0.76**	0.39	0.72	0.68				
12	Testes number	0.32	0.24	0.29	0.15	0.21	0.12	0.09	0.42	0.31	0.05	0.16	0.36			
13	Haptor length	0.57	0.67	0.14	0.35	0.60	0.56	0.39	0.72	0.29	0.40	0.51	0.68	0.24		
14	Clamp length	0.43	0.57	0.43	0.07	0.27	0.43	0.21	0.46	0.14	0.30	0.08	0.27	0.11	0.44	
15	Clamp number	0.09	0.08	0.23	0.29	0.14	0.10	0.37	0.21	0.29	0.30	0.17	0.06	0.74	0.13	0.50

Abbreviations: AE anterior extremity

monogenean genera, *Microcotyle* spp. parasitise many unrelated fishes, and some species are widely distributed. Consequently, identification based on host and locality may be erroneous. Therefore, despite the numerous revisions of this genus which have resulted in the scope and diagnosis of *Microcotyle* being rather well resolved, the identification of species within the genus is still generally problematical.

Mamaev (1989) suggested using the presence or absence of spines in the posterolateral "pockets" of the genital atrium, the general form of the latter and its armament as good diagnostic characters. The absolute size and the exact shape of the genital atrium were recognised by him as the least informative. However, the features listed by Mamaev (1989) as the most significant are almost identical in all of the species compared in the present work. Nevertheless, the exact shape of the genital atrium of the new species is very conservative in all of the specimens investigated; this is so even in juvenile worms, at a stage when the atrium is just beginning to form, as it already has its specific shape. In addition, the length of the genital atrium was found to be independent of body length, and the atrial length/width ratio which describes its shape proved to be very informative for differentiating *M. omanae* from its most morphologically closely related species.

The ratio of the length of the buccal organs in relation to the length of the pharynx has also been indicated as a likely stable character (Mamaev, 1989). However, as shown above, this ratio is highly dependent on body size (Table 2), so, despite the fact that the dimensions of this feature appear to readily distinguish the new species from its congeners (Table 1), its use for species differentiation is questionable. Moreover, since the length of the pharynx is independent of body length (Table 2), the larger the body, the greater the ratio between the length of the buccal organs and that of the pharynx. Therefore, although the pharynx was markedly smaller than the buccal organs in all of the studied specimens (Table 1), this character must also be regarded as unreliable.

The distances from the anterior extremity of the body to the margins of the internal organs and their sizes, which are commonly used in descriptions of *Microcotyle* spp. are also found to be body-length-dependent (Table 2). Perhaps the ratio between these

distances and the length of the body may be more effective for species differentiation.

On the other hand, analyses of the measurements of *M. omanae* showed no significant effect of the body size of adult worms on such characters as the number of clamps and testes. This is in contrast with the data for these structures given by other authors (Table 1; Thoney & Munroe, 1987; Williams, 1991) indicating significant differences between specimens of the same species. Perhaps this may be due to variation caused by geographical or host differences, or to data from juvenile worms being included in the descriptions. A relationship with body size was also not found for the length of the haptor (Table 2), since although its length increases with age, the body apparently grows faster throughout the life span of the worm, and consequently, on average, the haptor comprises half of the total body length in juvenile worms but only a quarter in adult worms (Fig. 2).

Thus, seven of analysed measurements, namely the length of the pharynx, genital atrium and vitello-vaginal duct, the number of testes and clamps, plus the size of the latter, were independent of body length and suggested for the differentiation of *M. omanae* n. sp. from the similar, but smaller, species.

Obviously, for an unambiguous decision on the taxonomic significance of the various morphological characters of *Microcotyle* spp., there is a need of careful reinvestigation of the representatives of this genus using statistical methods in order to estimate both their morphometric variability and their dependence on body size and/or worm age.

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References

Al-Abdessalaam, Th. Z. S. (1995). Marine species of the Sultanate of Oman. Ministry of Agriculture and Fisheries Wealth, pp. 283–285.

Caballero y Caballero, E., & Bravo-Hollis, M. (1972). Monogenea (van Beneden, 1858) Carus, 1863 de peces marinos del litoral Mexicano del Golfo de Mexico y del Mar Caribe. *V. Revista de Biologia Tropical, 20*, 151–165.

Catalano, S. R., Hutson, K. S., Ratcliff, R. M., & Whittington, I. D. (2010). Redescriptions of two species of microcotylid monogeneans from three arripid hosts in southern Australian waters. *Systematic Parasitology, 76*, 211–222.

Chisholm, L. A., Beverley-Burton, M., & McAlpine, D. F. (1991). *Paueironfibula subsolana* n. sp. (Monogenea: Microcotylidae) from *Morone americana* (Perciformes: Percichthyidae) collected in fresh water in New Brunswick. *Canada. Journal of Parasitology, 77*, 901–905.

Cruz E Silva, M. P., Freitas, M. S., & Orge, M. L. (1997). Co-infection by monogenetic trematodes of the genus *Microcotyle* V. Beneden & Hesse 1863, *Lamellodiscus ignoratus* Palombi, 1943, the protozoan *Trichodina* sp. Ehrenberg, 1838 and the presence of epitheliocystis, *Vibrio algynoliticus* and *V. vulnificus* in cultured seabream (*Sparus aurata* L.) in Portugal. *Bulletin of the European Association of Fish Pathologists, 17*, 40–42.

Dillon, W. A., Hargis, W. J, Jr. & Harrises, A. E. (1984). [Monogeneans from the southern Pacific Ocean. Polyopisthocotyleids from Australian fishes. Subfamily Microcotylinae]. *Zoologicheskii Zhurnal, 63*, 348–359. (In Russian).

Gibson, D. I., Bray, R. A., & Harris, E. A. (Compilers) (2005). Host-Parasite Database of the Natural History Museum, London. URL http://www.nhm.ac.uk/research-curation/scientific-resources/taxonomy-systematics/host-parasites/database/index.jsp.

Hadi, R., & Bilqees, F. M. (2010). *Microcotyle rubrum* n. sp. (Monogenea: Microcotylidae) from *Otolithus ruber* of Karachi coast. *Pakistan. Proceedings of Parasitology, 50*, 115–126.

Hadi, R., & Bilqees, F. M. (2011). *Microcotyle argenticus* n. sp. (Monogenea) on the fish *Pampus argenticus* from Karachi coast. *Proceedings of Parasitology, 51*, 99–111.

Hadi, R., Bilqees, F. M., & Khatoon, N. (2011). *Microcotyle jonii* n. sp. of (Monogenea: Microcotylidae) in the fish *Lutjanus jonii* from Karachi coast. *Proceedings of Parasitology, 52*, 69–81.

Kim, K. H., H, Lee, E. H., Kwon, S. R., & Cho, J. B. (2001) Treatment of *Microcotyle sebastis* infestation in cultured rockfish *Sebastes schlegeli* by oral administration of praziquantel in combination with cimetidine. *Diseases of Aquatic Organisms, 44*, 133–136.

MacCallum, G. A., & MacCallum, W. G. (1913). Four species of *Microcotyle*, *M. pyragraphorus, macroura*, *eueides* and *acanthophallus*. *Zoologische Jahrbücher. Abteilung für Systematik, 34*, 223–244.

Mamaev, Yu. L. (1977). [On one of classifications of monogeneans of the family Microcotylidae]. *Parazitologiya, 11*, 98–103 (in Russian).

Mamaev, Yu. L. (1986). The taxonomical composition of the family Microcotylidae Taschenberg, 1879 (Monogenea). *Folia Parasitologica, 33*, 199–206.

Mamaev, Yu. L. (1989). [On species composition and morphological features of the genus *Microcotyle* (Microcotylidae, Monogenoidea).] In: Lebedev, B. I. (Ed.) [*Investigations in Parasitology, collection of papers*.] Vladivostok: DVNTs SSSR, pp. 32–38 (In Russian).

Mamaev, Yu. L., & Egorova, T. P. (1977). [A description of *Sebasticotyle ochotense* n. g., n. sp., a new monogenea from scorpion fishes and the erection of *Jaliscia* n. g.] *Trudy Biologo-Poshvennogo Instituta. Novaya seriya, 47*, 101–105 (In Russian).

Mamaev, Yu. L., & Lebedev, B. I. (1979). The system of higher monogeneans in the light of recent knowledge. *Zoologica Scripta, 8*, 13–18.

Merella, P., Cherchi, S., Garippa, G., Fioravanti, M. L., Gustinelli, A., & Salati, F. (2009). Outbreak of *Sciaenacotyle panceri* (Monogenea) on cage-reared meagre *Argyrosomus regius* (Osteichthyes) from the western Mediterranean Sea. *Diseases of Aquatic Organisms, 86*, 169–173.

Mladineo, I., & Maršić-Lučić, J. (2007). Host switch of *Lamellodiscus elegans* (Monogenea: Monopisthocotylea) and *Sparicotyle chrysophrii* (Monogenea: Polyopisthocotylea) between cage-reared sparids. *Veterinary Research Communications, 31*, 153–160.

Paperna, I., & Overstreet, R. M. (1981). Chapter 13: Parasites and diseases of mullets (Muligidae). In: Oren, O. H. (Ed.) *Aquaculture of grey mullets*. International Biological Programme Synthesis Series 26. Cambridge: Cambridge University Press, pp. 411–493.

Parukhin, A. M. (1989). [Parasitic worms of bottom fishes of the southern seas.] Kiev: Naukova Dumka, 155 pp (In Russian).

Radujkovic, B. M., & Euzet, L. (1989). Parasite des poissons marins du Monténégro: Monogènes. *Acta Adriatica, 30*, 51–135.

Randall, J. E. (1995). Coastal fishes of Oman. Australia: Crawford House Publishing Pty Ltd Bathurst, 439 pp.

Roskin, G. I., & Levinson, L. B. (1957). [Microscopic Techniques]. Moscow: Sovetskaya Nauka, 467 pp (In Russian).

Sandars, D. F. (1944). A contribution to the knowledge of the Microcotylidae of Western Australia. *Transactions of the Royal Society of South Australia, 68*, 67–81.

Sandars, D. F. (1945). Five new microcotylids from fish from Western Australian waters. *Journal of the Royal Society of Western Australia, 29*, 107–135.

Sanz, F. (1992). Mortality of cultured seabream *Sparus aurata* caused by an infection with a trematode of the genus *Microcotyle*. *Bulletin of the European Association of Fish Pathologists, 12*, 186–188.

Thoney, D. A., & Hargis, W. J. (1991). Monogenea Plathyhelminthes as hazards for fish in confinement. *Annual Review of Fish Diseases*, *1*, 133–135.

Thoney, D. A., & Munroe, T. A. (1987). *Microcotyle hiatulae* Goto, 1900 (Monogenea), a senior synonym of *M. furcata* Linton, 1940, with a redescription and comments on postlarval development. *Proceedings of the Helminthological Society of Washington, 54*, 91–95.

Tripathi, Y. R. (1956). Studies on the parasites of Indian fishes. IV. Trematoda: Monogenea, Microcotylidae. *Records of the Indian Museum*, 52 (2–4) (1954), 231–247.

Unnithan, R. V. (1971). On the functional morphology of a new fauna of Monogenoidea of fishes from Trivandrum and Environs. Part IV. Microcotylidae sensu stricto and its repartition into subsidiary taxa. *American Midland Naturalist, 85*, 366–398.

Williams, A. (1991). Monogeneans of the families Microcotylidae Taschenberg, 1879 and Heteraxinidae Price, 1962 from Western Australia, including the description of *Polylabris sandarsae* n. sp. (Microcotylidae). *Systematic Parasitology, 18*, 17–43.

Yamaguti, S. (1963). *Systema helminthum*. Vol. IV. *Monogenea and Aspidocotylea*. New York: Interscience Division, John Wiley & Sons, 699 pp.

Zhang J. -Y., Yang T. -B., & Liu L. (Eds) (2001). *Monogeneans of Chinese marine fishes*. Beijing: Agriculture Press, 400 pp (In Chinese).