

New Data on the Genus *Paracentrophyes* (Homalorhagida, Kinorhyncha), with the Description of a New Species from the West Pacific

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Abstract: The kinorhynch genus *Paracentrophyes* currently consists of two species only: *P. quadridentatus* (Zelinka, 1928) from the Mediterranean Sea and *P. praedictus* Higgins, 1983 from Belize in the Caribbean. Both species have until now been recorded from their type localities only. In the present contribution a new species of *Paracentrophyes*, *P. anurus* sp. nov., is described from the Korea Strait. The species can be recognized by details in the mouth cone morphology, absence of perispinal setae in segment 10, and absence of a midterminal process in both sexes. Female specimens are furthermore characterized by the presence of an extraordinary long middorsal spine on segment 10, whereas males possess a midterminal type 3 sensory spot. Besides the recording of the new species, the occurrence of *P. cf. quadridentatus* is reported from two localities in the Atlantic Ocean (Faeroe Islands and Spain). The recorded specimens are described in detail, based on combined examinations with LM and SEM, and diagnostic traits for all three species of *Paracentrophyes* are discussed in light of the newly acquired information. Furthermore, an emended terminology for positions of cuticular trunk structures is proposed.

Keywords: Korea, *Paracentrophyes anurus* sp. nov., meiofauna, taxonomy.

INTRODUCTION

During his extensive study of the Mediterranean kinorhynch fauna, Zelinka [1] described two atypical species that were assigned to the homalorhagid genus *Pycnophyes*. Unlike other *Pycnophyes* the two species, *P. quadridentatus* Zelinka, 1928 and *P. flagellatus* Zelinka, 1928, did not have completely differentiated episternal and midsternal plates on segment 1, and unpaired spines were present on the two posteriormost segments. These morphological deviations from all other species in the genus made their taxonomic position doubtful. When Higgins [2], about fifty years later, explored the meiobenthos of the coral reef community at Carrie Bow Cay, Belize, he collected a new species displaying this special and unique combination of characters and he erected the genus *Paracentrophyes* to accommodate the new species, *P. praedictus* Higgins, 1983, and assigned it to the homalorhagid family Neocentrophyidae. Based on the sexual dimorphism observed in *P. praedictus*, he concluded that Zelinka's *Pycnophyes quadridentatus* and *P. flagellatus* represented the female and male, respectively, of the same species and assigned them to *Paracentrophyes* under the name *Paracentrophyes quadridentatus* [2]. The class homalorhagida currently consists of four genera.

The two diverse genera *Pycnophyes* and *Kinorhynchus* with 42 and 19 valid species, respectively, and the two smaller genera *Neocentrophyes* and *Paracentrophyes* with only two known species in each. Even though it accommodates two species only, *Paracentrophyes* is not a taxonomically unproblematic genus. Opposed to *P. praedictus* that is well described and has been examined thoroughly in subsequent studies [3], *P. quadridentatus* is poorly described and has not been reported since Zelinka found it in the Bay of Naples. Based on the information given in Zelinka's original descriptions, it is currently not possible to identify *P. quadridentatus* with certainty, which stresses the urgent need for a redescription of the species, based on specimens collected from the type locality.

Currently, the genus' known distribution range is restricted to the Mediterranean and the Tropical West Atlantic. In the present contribution we report the recording of *Paracentrophyes* from a locality in the Korea Strait and from two localities in the North Atlantic, off the North Coast of the Iberian Peninsula and in a fjord in the Faeroe Islands. Due to the problematic status of *P. quadridentatus*, we can only tentatively identify the North Atlantic specimens as *Paracentrophyes cf. quadridentatus*, whereas the Korean recording represents a new species. The new species is described, and new information about introvert and cuticular trunk morphology are given for *P. cf. quadridentatus*.

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Sublateral and Lateral Accessory

The terms are commonly used for positions in between midlateral and lateroventral in cyclorhagid kinorhynchs. However, due to the different trunk shape in homalorhagids, the area between the midlateral and lateroventral positions is extremely minimized, which makes location of additional positions here inapplicable.

Lateroventral

Narrow lines on the tergal plate immediately adjacent to the tergo-sternal junction. Structures in lateroventral positions were not recorded in any of the examined species of *Paracentrophyes*, but the positions are applicable for species of other homalorhagid genera.

Ventrolateral

Moderately narrow bands on the sternal plates, immediately adjacent to the tergo-sternal junctions. In species of *Paracentrophyes* the ventrolateral positions would often be occupied by perispinal setae (see vlse on Fig. 2B) or sensory spots (see vlss on Fig. 2B).

Ventromedial

Broad bands, medially on each sternal plate. In species of *Paracentrophyes* the ventromedial positions would often be occupied by sensory spots (see vmss on Fig. 2B).

Paraventral

Moderately narrow bands on the sternal plates, immediately adjacent to the midsternal junction. Structures

Table 1. Morphometric Data for Examined Female Specimens of *Paracentrophyes*: *P. anurus* sp. nov., *P. cf. quadridentatus* Spanish Population (*P. cf. q. Spain*), *P. cf. quadridentatus* Faroese Population (*P. cf. q. Faeroes*), and *P. praedictus*, Including Data Made Available by Zelinka (1928) for Type Material of *P. quadridentatus*

Character	<i>P. anurus</i> n. sp.		<i>P. quadridentatus</i>	<i>P. cf. q. Spain</i>		<i>P. cf. q. Faeroes</i>		<i>P. praedictus</i>	
	Holotype KIN-341	Paratype KIN-343	Holotype			KIN-112	KIN-113	Allotype and 7 paratypes USNM 69989 and 69989	
								Range	Mean
TL	630 µm	630 µm	370 µm	610 µm	539 µm	592 µm	568 µm	339 – 503 µm	425 µm
MSW	162 µm	161 µm	123 µm	156 µm	136 µm	162 µm	160 µm	114 – 131 µm	123 µm
MSW/TL	25,7 %	25,6 %	33,2 %	25,6 %	25,3 %	27,4 %	28,2 %	26,0 – 36,0 %	29,2 %
S1	96 µm	101 µm 48 µm	65 µm	114 µm	100 µm	96 µm	100 µm	60 - 72 µm	66 µm
S2	54 µm	50 µm	27 µm	48 µm	43 µm	48 µm	43 µm	32 – 45 µm	37 µm
S3	56 µm	52 µm	27 µm	47 µm	45 µm	55 µm	43 µm	35 – 46 µm	39 µm
S4	58 µm	58 µm	31 µm	48 µm	52 µm	59 µm	48 µm	36 – 48 µm	40 µm
S5	60 µm	63 µm	31 µm	47 µm	57 µm	60 µm	48 µm	38 – 48 µm	42 µm
S6	64 µm	71 µm	38 µm	55 µm	56 µm	60 µm	64 µm	40 – 54 µm	44 µm
S7	64 µm	72 µm	38 µm	67 µm	57 µm	60 µm	64 µm	42 – 59 µm	47 µm
S8	68 µm	70 µm	42 µm	67 µm	58 µm	64 µm	64 µm	43 – 60 µm	48 µm
S9	56 µm	56 µm	46 µm	82 µm	62 µm	65 µm	64 µm	40 – 58 µm	47 µm
S10	46 µm	42 µm	38 µm	72 µm	54 µm	59 µm	59 µm	36 – 48 µm	40 µm
S11	38 µm	143 µm	23 µm	43 µm	46 µm	52 µm	47 µm	28 – 38 µm	32 µm
SW 1	134 µm	150 µm	110 µm	135 µm	129 µm	144 µm	144 µm	104 – 113 µm	111 µm
SW 2	136 µm	154 µm	123 µm	152 µm	131 µm	154 µm	151 µm	112 – 123 µm	118 µm
SW 3	148 µm	156 µm	123 µm	151 µm	135 µm	158 µm	154 µm	113 – 126 µm	120 µm
SW 4	156 µm	161 µm	123 µm	155 µm	136 µm	158 µm	158 µm	114 – 129 µm	121 µm
SW 5	162 µm	161 µm	123 µm	156 µm	134 µm	159 µm	160 µm	114 – 131 µm	123 µm
SW 6	162 µm	161 µm	123 µm	153 µm	134 µm	162 µm	160 µm	114 – 131 µm	123 µm
SW 7	162 µm	161 µm	123 µm	154 µm	133 µm	162 µm	160 µm	114 – 131 µm	123 µm
SW 8	162 µm	147 µm	123 µm	147 µm	127 µm	162 µm	160 µm	114 – 131 µm	123 µm
SW 9	150 µm	124 µm	110 µm	139 µm	123 µm	157 µm	159 µm	107 – 125 µm	116 µm
SW 10	130 µm	91 µm	100 µm	116 µm	104 µm	145 µm	144 µm	94 – 113 µm	103 µm
SW 11	98 µm	13 µm	77 µm	90 µm	83 µm	104 µm	112 µm	71 – 86 µm	79 µm
ML 10	13 µm	13 µm	23 µm	Broken	18 µm	26 µm	25 µm	11 – 14 µm	12 µm
MD 10	50 µm	56 µm	27 µm	Broken	26 µm	25 µm	30 µm	18 – 26 µm	23 µm
MD 11	Broken	40 µm	65 µm	Broken	48 µm	52 µm	43 µm	31 – 52 µm	41 µm
LTS	61 µm	62 µm	96 µm	Broken	103 µm	126 µm	135 µm	95 – 121 µm	108 µm

Abbreviations: LTS: lateral terminal spine; ML: midlateral spine; MD: middorsal spine; MSW: maximum sternal width; S: segment length; SW: sternal width; TL: trunk length.

Table 2. Morphometric Data for Examined Male Specimens of *Paracentrophyes*: *P. anurus* sp. nov., *P. cf. quadridentatus* Spanish Population (*P. cf. q. Spain*), *P. cf. quadridentatus* Faroese Population (*P. cf. q. Faeroes*), and *P. praedictus*, Including Data Made Available by Zelinka (1928) for Type Material of *P. quadridentatus*

Character	<i>P. anurus</i> n. sp.	<i>P. quadridentatus</i>	<i>P. cf. q. Spain</i>	<i>P. cf. q. Faeroes</i>		<i>P. praedictus</i>	
	Allotype KIN-342	Allotype		KIN-107	KIN-116	8 paratypes USNM 69989	
						Range	Mean
TL	606 µm	595 µm	549 µm	669 µm	574 µm	332 – 438 µm	392 µm
MSW	133 µm	116 µm	143 µm	160 µm	156 µm	100 – 116 µm	110 µm
MSW/TL	21,9 %	19,5 %	26,1 %	23,9 %	27,2 %	24,2 – 33,1 %	28,3 %
S1	96 µm	92 µm	98 µm	102 µm	99 µm	57 – 69 µm	62 µm
S2	39 µm	46 µm	46 µm	44 µm	49 µm	28 – 39 µm	33 µm
S3	43 µm	46 µm	46 µm	52 µm	50 µm	31 – 41 µm	36 µm
S4	56 µm	50 µm	46 µm	57 µm	50 µm	34 – 42 µm	37 µm
S5	62 µm	54 µm	43 µm	61 µm	51 µm	36 – 44 µm	39 µm
S6	63 µm	54 µm	47 µm	70 µm	51 µm	37 – 47 µm	41 µm
S7	63 µm	58 µm	59 µm	72 µm	57 µm	40 – 51 µm	43 µm
S8	62 µm	58 µm	58 µm	76 µm	65 µm	40 – 53 µm	44 µm
S9	64 µm	61 µm	57 µm	75 µm	62 µm	38 – 51 µm	43 µm
S10	47 µm	46 µm	59 µm	61 µm	56 µm	33 – 38 µm	37 µm
S11	45 µm	23 µm	36 µm	44 µm	35 µm	22 – 29 µm	26 µm
SW 1	133 µm	110 µm	138 µm	133 µm	139 µm	96 – 111 µm	103 µm
SW 2	127 µm	116 µm	138 µm	143 µm	142 µm	99 – 112 µm	107 µm
SW 3	130 µm	116 µm	139 µm	150 µm	148 µm	100 – 113 µm	108 µm
SW 4	131 µm	116 µm	141 µm	153 µm	154 µm	100 – 116 µm	110 µm
SW 5	131 µm	116 µm	142 µm	160 µm	156 µm	100 – 116 µm	110 µm
SW 6	132 µm	116 µm	143 µm	160 µm	156 µm	100 – 116 µm	110 µm
SW 7	133 µm	116 µm	143 µm	160 µm	156 µm	97 – 112 µm	107 µm
SW 8	133 µm	116 µm	143 µm	157 µm	153 µm	90 – 110 µm	103 µm
SW 9	121 µm	116 µm	132 µm	148 µm	140 µm	75 – 102 µm	97 µm
SW 10	113 µm	100 µm	100 µm	130 µm	121 µm	69 – 88 µm	82 µm
SW 11	94 µm	85 µm	82 µm	102 µm	94 µm	60 – 65 µm	63 µm
MD 10	Broken	–	Broken	76 µm	68 µm	48 – 72 µm	59 µm
MD 11	79 µm	58 – 61 µm	Broken	74 µm	69 µm	50 – 74 µm	60 µm
PS	62 µm	61 µm	69 µm	73 µm	63 µm	42 – 61 µm	53 µm
LTS	47 µm	77 µm	101 µm	111 µm	118 µm	63 – 78 µm	70 µm

Abbreviations: LTS: lateral terminal spine; MD: middorsal spine; MSW: maximum sternal width; PS: penile spine; S: segment length; SW: sternal width; TL: trunk length. A dash (–) indicates that data is not available.

Table 3. Summary of Nature and Location of Sensory Spots, Setae, Spines and Spinous Processes Arranged by Series in *Paracentrophyes anurus* sp. nov. from the Korea Strait

Position Segment	MD	PD	SD	LD	PL	ML	VL	VM
1	sp	se	ss1	ss1 ss1 ss1	se ss1	sp	se ss1	ss1 ss1 (f)
2	sp	se	ss1 ss1	ss1 ss1 ss1 ss1	se	sp	se	ss1 ss1
3	sp	se	ss1 ss1	ss1 ss1	se	sp	se	ss1 ss1
4	sp	se	ss1 ss1	ss1 ss1	se	sp	se	ss1 ss1
5	sp	se	ss1	ss1 ss1	se	sp	se	ss1 ss1
6	sp	se	ss1 ss1	ss1 ss1	se	sp	se	ss1 ss1
7	sp	se	ss1	ss1 ss1	se	sp	se	ss1 ss1
8	sp	se	ss1 ss1	ss1 ss1	se	sp	se	ss1 ss1
9	sp	se	ss1 ss1 ss1	ss1	se	sp	se	ss1 ss1
10	ac		ss1 ss1 ss1	ps (m) ss1		ac (f)	ss1	ss1
11	ac ss3 (m)		ss3 ss3	ps (m)		lts		ss1 ss3

Abbreviations: ac, acicular spine; (f): female condition of sexually dimorphic character; lts: lateral terminal spine; (m): male condition of sexually dimorphic character; ps, penile spine; ss1/3: sensory spot type 1/3; se, perispinal seta; sp, spinous process. LD: laterodorsal; MD: middorsal; ML: midlateral; PD: paradorsal; PL: paralateral; SD: subdorsal; VL: ventrolateral; VM: ventromedial.

Fig. (6). Light micrographs showing cuticular and internal details in female holotype (**A-F**) and paratype (**G**) of *Paracentrophyes anurus* sp. nov. (**A**) Segment 1, dorsal view. (**B**) Segment 1, ventral view. (**C**) Entire animal, ventral view. (**D**) Segments 7 and 8, dorsal view. (**E**) Segments 7 and 8, ventral view. (**F**) Detail showing middorsal to subdorsal parts of segment 8. (**G**) Segments 9 to 11, dorsal view. Abbreviations: emj, episternal-midsternal junction; ldss, laterodorsal sensory spot; mlp, midlateral process; mdp, middorsal process; mds, middorsal spine; pdse, paradorsal seta; sdss, subdorsal sensory spot.

Trunk

The trunk has eleven segments (Figs. **2A-B**, **6C**). Segment 1 consists of one tergal and one sternal plate. Incomplete lines showing a partial subdivision into paired episternal plates and an unpaired midsternal plate are indicated on the anterior part of the sternal plate (Figs. **2B**, **4E**, **6B**). Segments 2 to 10 are composed of one tergal and two sternal plates, and segment 11 of one tergal and a single sternal plate (Figs. **2B**, **5E**, **G**, **6E**). The sternal plates are flattened, whereas the tergal plate is steeply vaulted, making the trunk conspicuously triangular in cross-section (Fig. **5F**). The segment width is fairly constant throughout the whole trunk, but the maximum width is reached at segment 5, and retained until segment 8 (segments 3 to 8 in males), from which the segments gradually turn narrower (see also Tables **1-2**, **5**). The cuticle is of medium thickness and pachycycli are generally indistinct (Fig. **6**). All segments

have densely set scale-like cuticular hairs, interrupted by less hirsute areas around some sensory spots and prominent laterodorsal muscle attachment sites on segments 1 to 10. Posterior segment margins finely serrated, but an actual pectinate fringe is not present. Secondary pectinate fringes on anterior part of segments not present.

Segment 1 with middorsal and midlateral spinose processes (Figs. **2A**, **4F**, **6A**). Spinose processes with acicular pointed tips, and flanked by paradorsal or paralateral and ventrolateral perispinal setae. Anterior segment margin covered by overhanging placids when visualized with SEM (Fig. **4D-E**). In LM the anterior segment margins appear finely denticulated (Fig. **6A**). Anterolateral margins of segment extend into horn-like processes. Tergal plate with five pairs of sensory spots, and sternal plate with three pairs (two in males) (see Fig. **2A-B** and Table **3** for exact location). All sensory spots are rounded to elongate and appear slightly elevated due to the projecting papillae. The

sensory spots on this and the following segments may have one and up to three pores (Fig. 5A-C). Those with two or three pores resemble two or three partly merged “single pore” sensory spots. The number of pores in each particular sensory spot varies among the examined specimens.

Segment 2 with middorsal and midlateral spinose processes appearing as those on the previous segment. Spinose processes flanked by paradorsal or paralateral and ventrolateral setae. Six pairs of sensory spots evenly

distributed over the tergal plate in the subdorsal and laterodorsal positions (Fig. 2A); both single and double pored sensory spots present (Fig. 5B). Sternal plates with two pairs of ventromedial sensory spots; sensory spots elongate to droplet shaped with a cilium emerging through the single pore.

Segments 3 and 4 similar with previous segment, but with only four pairs of sensory spots on the tergal plate (Fig. 2A).

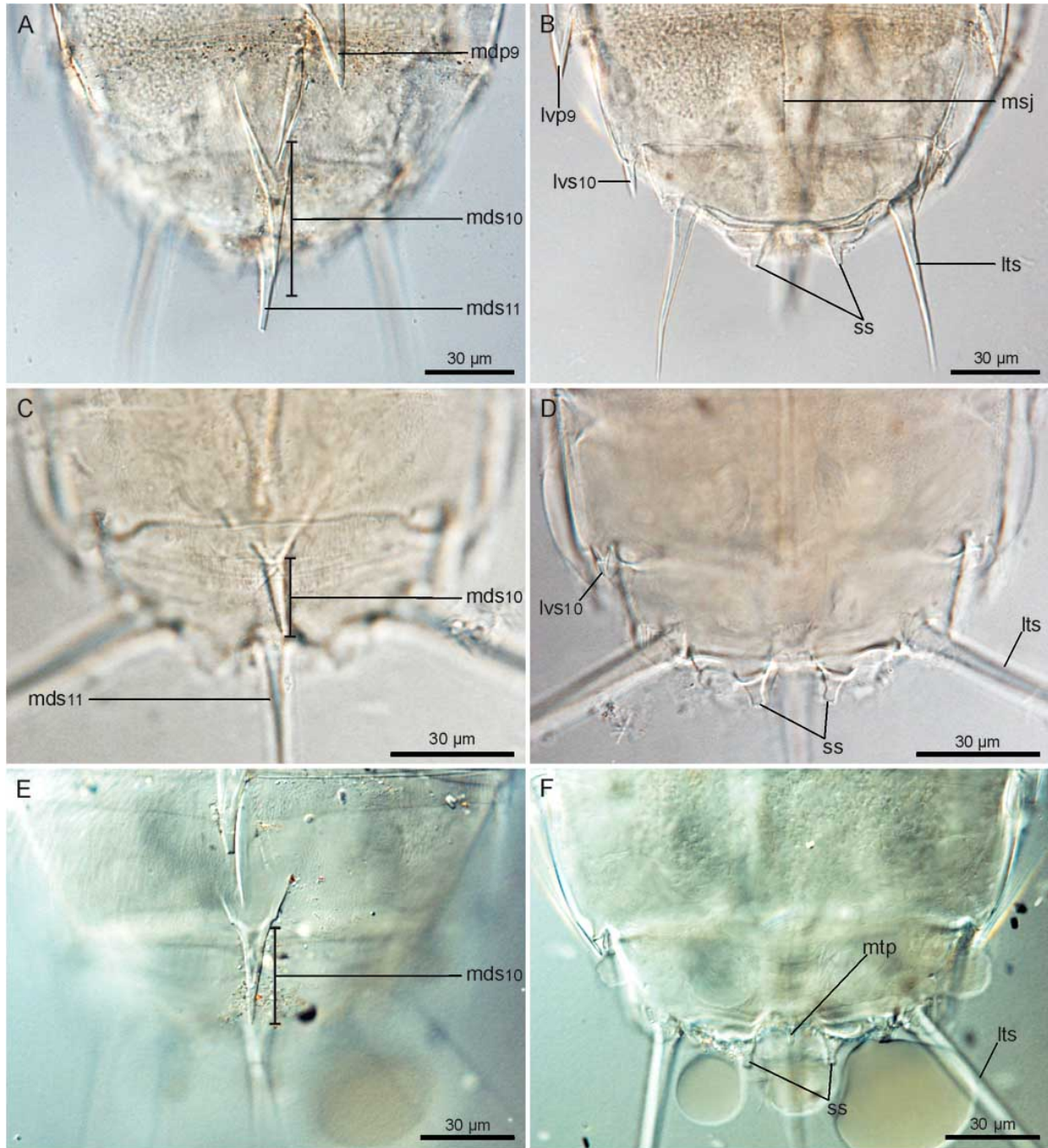


Fig. (7). Light micrographs showing terminal segments in female specimens of three species of *Paracentrophyes*: (A) *P. anurus* sp. nov. dorsal view and (B) ventral view. (C) *P. praedictus* dorsal view and (D) ventral view. (E) *P. cf. quadridentatus* (Faroese population) dorsal view and (F) ventral view. Abbreviations: lts, lateral terminal spine; mdp, middorsal process; mds, middorsal spine; mlp, midlateral process; mls, midlateral spine; msj, midsternal junction; mtp, midterminal process; vmss, ventromedial sensory spot. Digit after the labels refers to the segment number.

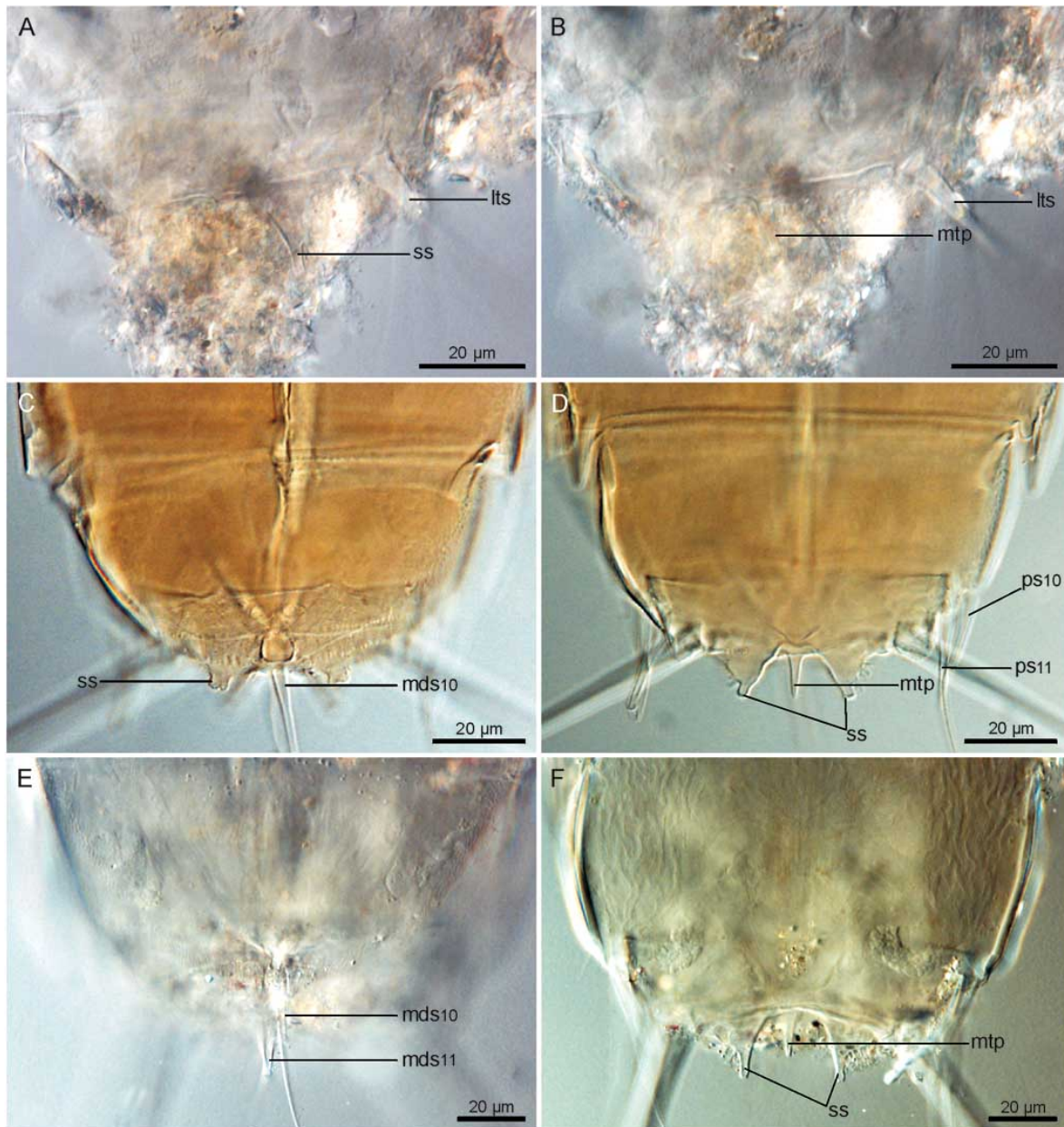


Fig. (8). Light micrographs showing terminal segments in male specimens of three species of *Paracentrophyes*: (A-B) *P. anurus* sp. nov. ventral view but yet two slightly different focus planes. (C) *P. praedictus* dorsal view and (D) ventral view. (E) *P. cf. quadridentatus* (Faroese population) dorsal view and (F) ventral view. Abbreviations: lts, lateral terminal spine; mtp, midterminal process; mds, middorsal spine; ps, penile spine; sdss, subdorsal sensory spot; vmss, ventromedial sensory spot. Digit after the labels refers to the segment number.

Segment 5 generally similar with previous two segments, but with three pairs of sensory spots only. Basis of middorsal spinose process slightly stronger than on previous segments.

Segment 6 similar with segments 3 and 4. Basis of middorsal spinose process slightly stronger than on previous segment.

Segment 7 similar with segment 5. Basis of middorsal spinose process slightly stronger than on previous segment.

Segments 8 and 9 generally similar with segments 3, 4 and 6. Bases of middorsal and midlateral spinose processes strong; processes stout and short, without acicular pointed tip (Fig. 6D-F).

Segment 10 without spinose processes and perispinal setae (Fig. 2A). Both sexes with a middorsal spine present, extending beyond posterior margin of segment 11 (Figs. 2A, C, 5F, 6G, 7A); middorsal spine pointed and rigid in females, flexible and soft in males. Females with one pair of short, pointed midlateral spines (Figs. 5G, 7B); males with one pair of laterodorsal, flexible penile spines (Figs. 2C, 5E). Tergal plate with three pairs of subdorsal and one pair of laterodorsal sensory spots; sternal plate with one pair of ventrolateral and one pair of ventromedial sensory spots (Figs. 2A-B, 5E, G).

Segment 11 short, barely projecting beyond previous segment. Middorsal spine and paired lateral terminal spines present (Figs. 2A-D, 5E-G, 6G, 7A-B); middorsal spine

pointed and rigid in females, flexible and soft in male; lateral terminal spines rigid in both sexes. Males furthermore with one pair of laterodorsal, flexible penile spines (Figs. 2C-D, 5E). Midterminal process absent in both sexes, but males possess a short midterminal modified (type 3) sensory spot (Figs. 2D, 5E, 8B). Two pairs of subdorsal and one pair of ventromedial type 3 sensory spots extend from the caudal part of the segment (Figs. 2A-D, 5F-G, 7B, 8A); single sternal plate with one pair of ventromedial type 1 sensory spots (Fig. 5G).

Habitat and Species Associations

The sediment consisted of subtidal coarse mud with tiny mollusk shell particles. *Paracentrophyes anurus* sp. nov. co-

occurred with another new the kinorhynch species *Condyloderes megastigma* [8], as well as other meiobenthic taxa such as nematodes (*Desmoscolex* sp., *Tricoma* sp., *T. (Quadricoma)* sp., *Dracograllus* sp., *Richtersia* sp., *Sphaerolaimus* sp., *Ceramonema* sp.), isopods, harpacticoids, halacarids, polychaetes and sipunculans.

Paracentrophyes praedictus Higgins, 1983

Material Examined

Female allotype (USNM 69988), eight male and thirteen female paratypes (USNM 69989) were examined and measured using light microscopy (see Tables 1 and 2 for measurements). The material was collected by R. P. Higgins

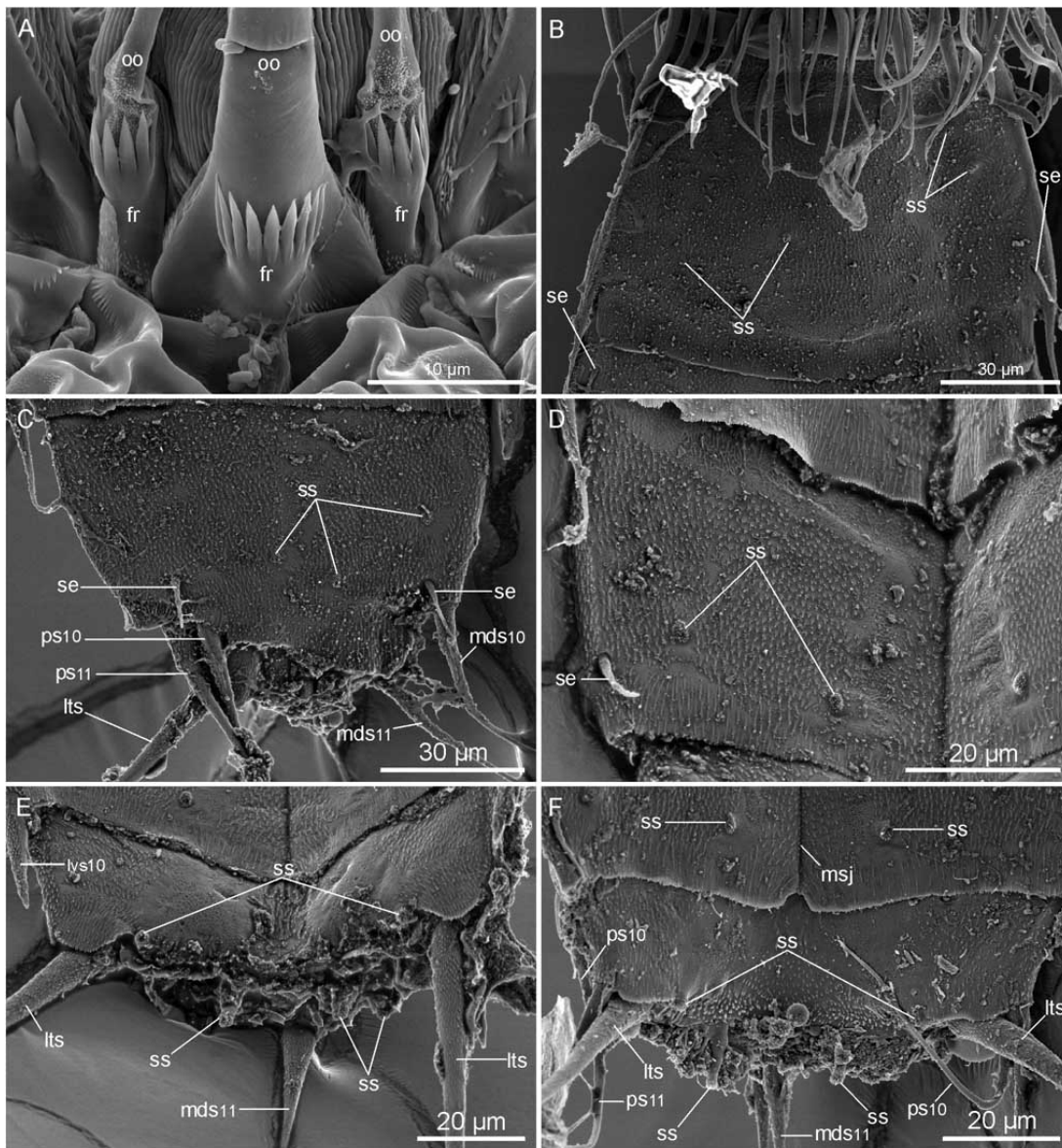


Fig. (9). Scanning electron micrographs showing cuticular head and trunk details in *Paracentrophyes* cf. *quadridentatus* from the Faroe Islands. (A) Outer oral styles alternating in size. (B) Segment 1, left lateral side of tergal plate. (C) Segments 10 and 11 in male, left lateral side of tergal plates. (D) Segment 10, right sternal plate. (E) Segments 10 and 11 in female, ventral view. (F) Segments 10 and 11 in female, ventral view. Abbreviations: fr, basal fringe on outer oral style; ldss, laterodorsal sensory spot; lts, lateral terminal spine; mds, middorsal spine; mls, midlateral spine; msj, midsternal junction; oo, outer oral style; pdse, paradorsal seta; plse, paralateral seta; ps, penile spine; sdss, subdorsal sensory spot; vlse, ventrolateral seta; vmss, ventromedial sensory spot. Digit after the labels refers to the segment number.

at Twin Cays, Belize and is stored at the National Museum of Natural History, Smithsonian Institution.

Brief Description

All specimens were measured, and some not previously published dimensions were examined (Tables 1-2). The morphology of the re-examined specimens generally confirmed the original description given by Higgins [2] (however, sensory spot positions could not be checked due to the beginning bleaching of the specimens), but attention was drawn to some characters of particular interest. The outer oral styles alternate in size, and both large and smaller styles are equipped with a short transverse pectinate fringe on the exterior surfaces of their bases. The pectinate fringe found on the large styles has twelve fringe tips that emerge from a somewhat indistinct basis, whereas the fringes on the smaller styles tend to wrap around the style and consist of eight fringe tips. Perispinal setae are present in paradorsal, paralateral and ventrolateral positions on segments 1 to 9. Males furthermore have one additional pair of paraventral setae on segment 1. Segment 10 shows one pair paradorsal and ventrolateral setae in males, and paralateral and ventrolateral setae in females. Males and females furthermore possess a middorsal spine on segment 10, but the female spine is short, rigid and hardly projecting upon posterior margin of the preceding segment (Fig. 7C). Both sexes also have two pairs of subdorsal (Fig. 8C) and one pair of ventromedial (Fig. 7D, 8D) type 3 sensory spots on segment 11. Opposed to females that have their ventromedial sensory spots projecting from short, rounded bases (Fig. 7D), males have their sensory spots elevated on the tip of a conspicuous triangular extension. The outer margin of each extension is irregular with short, thread-like outgrowths (Fig. 8D). Males also possess two pairs of penile spines, but one pair clearly emerge in a laterodorsal position from the posterior part of segment 10 (Fig. 8D), and not segment 11 as stated in the original description [2].

Paracentrophyes quadridentatus (Zelinka, 1928)

Brief Description

The type specimens collected by Zelinka in the Bay of Naples do not exist any longer, hence the only available information about the diagnostic traits for the species is contained in the original descriptions of *Pycnophyes quadridentatus* and *P. flagellatus* [1] that subsequently have been combined and reassigned to *Paracentrophyes* under the name *P. quadridentatus* [2]. The descriptions include some diagnostic traits and metric indices, but they do not present the amount of details required for a modern taxonomic study. Unfortunately, this limitation disables precise identification of specimens belonging to the species.

In his descriptions, Zelinka [1] provides selected measurements for a female (reported as *Pycnophyes quadridentatus*) and male (reported as *P. flagellatus*) specimen of *Paracentrophyes quadridentatus*. All reported measurements are summarized in Tables 1 and 2. The reported dimensions, as well as the provided line art illustrations, show that the trunk width is fairly constant in this species, with the sternal plates reaching their maximum width in segments 2 through 8 (9 in the male). They also show that the examined female was fairly short, only 370 µm in trunk length, compared to the male with a total trunk length of 595 µm. However, the measures for the males should be used with some caution. Usually the sum of all individual segment lengths will exceed the total trunk length, because the segments are slightly overlapping at the intersegmental joins. However, the sum of the reported individual segment lengths is 588 µm for males even though the reported total trunk length reaches 595 µm. Thus some of these measures must be imprecise.

Despite the lack of details in the descriptions, they still contribute with some significant information. Most importantly are the female characters showing a short middorsal

Table 4. Summary of Nature and Location of Sensory Spots (Not Available for Spanish Specimens), Setae, Spines and Spinous Processes Arranged by Series in *Paracentrophyes* cf. *quadridentatus* from the Faroe Islands and Spain

Position Segment	MD	PD	SD	LD	PL	ML	VL	VM
1	sp	se	ss1 ss1	ss1 ss1		sp	se ss1	ss1 ss1
2	sp	se	ss1 ss1ss1	ss1	se	sp	se	ss1 ss1
3	sp	se	ss1 ss1 ss1	ss1	se	sp	se	ss1 ss1
4	sp	se	ss1 ss1 ss1	ss1	se	sp	se	ss1 ss1
5	sp	se	ss1 ss1	ss1	se	sp	se	ss1 ss1
6	sp	se	ss1 ss1 ss1	ss1	se	sp	se	ss1 ss1
7	sp	se	ss1 ss1		se	sp	se	ss1 ss1
8	sp	se	ss1 ss1 ss1	ss1	se	sp	se	ss1 ss1
9	sp	se	ss1 ss1	ss1 ss1	se	sp	se	ss1 ss1
10	ac	se	ss1 ss1 ss1	ps(m)	se	ac(f)	se	ss1 ss1
11	ac mtp*		ss3 ss3	ps(m)		lts	ss3	ss1

Abbreviations: ac, acicular spine; (f): female condition of sexually dimorphic character; lts: lateral terminal spine; (m): male condition of sexually dimorphic character; mtp, midterminal process; ps, penile spine; ss1/3: sensory spot type 1/3; se, perispinal seta; sp, spinous process; * indicates that the presence of the character varies among the specimens. LD: laterodorsal; MD: middorsal; ML: midlateral; PD: paradorsal; PL: paralateral; SD: subdorsal; VL: ventrolateral; VM: ventromedial.

spine on segment 10 and the presence of a midterminal process. Zelinka furthermore illustrate the type 3 sensory spots on the terminal segment as being non-elevated, and marks the putative perforation site of a paralateral seta on the segment as being present at least in the female.

***Paracentrophyes* cf. *quadridentatus* – Faroe Islands population**

Material Examined

Two females (ZMUC KIN-112 and KIN-113) and two males (ZMUC KIN-107 and KIN-116) mounted for LM, and three males and one female mounted for SEM (MVS'

personal collection). All material is stored at the Zoological Museum, Natural History Museum of Denmark.

Brief Description

The four specimens mounted for LM were measured. See Tables 1 and 2 for measurements and dimensions, and Table 4 for summary of positions of outer cuticular structures.

The distributional pattern and general appearance of appendages on the mouth cone and introvert are identical with the conditions found in *P. anurus* sp. nov. (see Fig. 3). The pectinate fringe found on the large outer oral styles has nine fringe tips, whereas the fringes on the smaller styles that

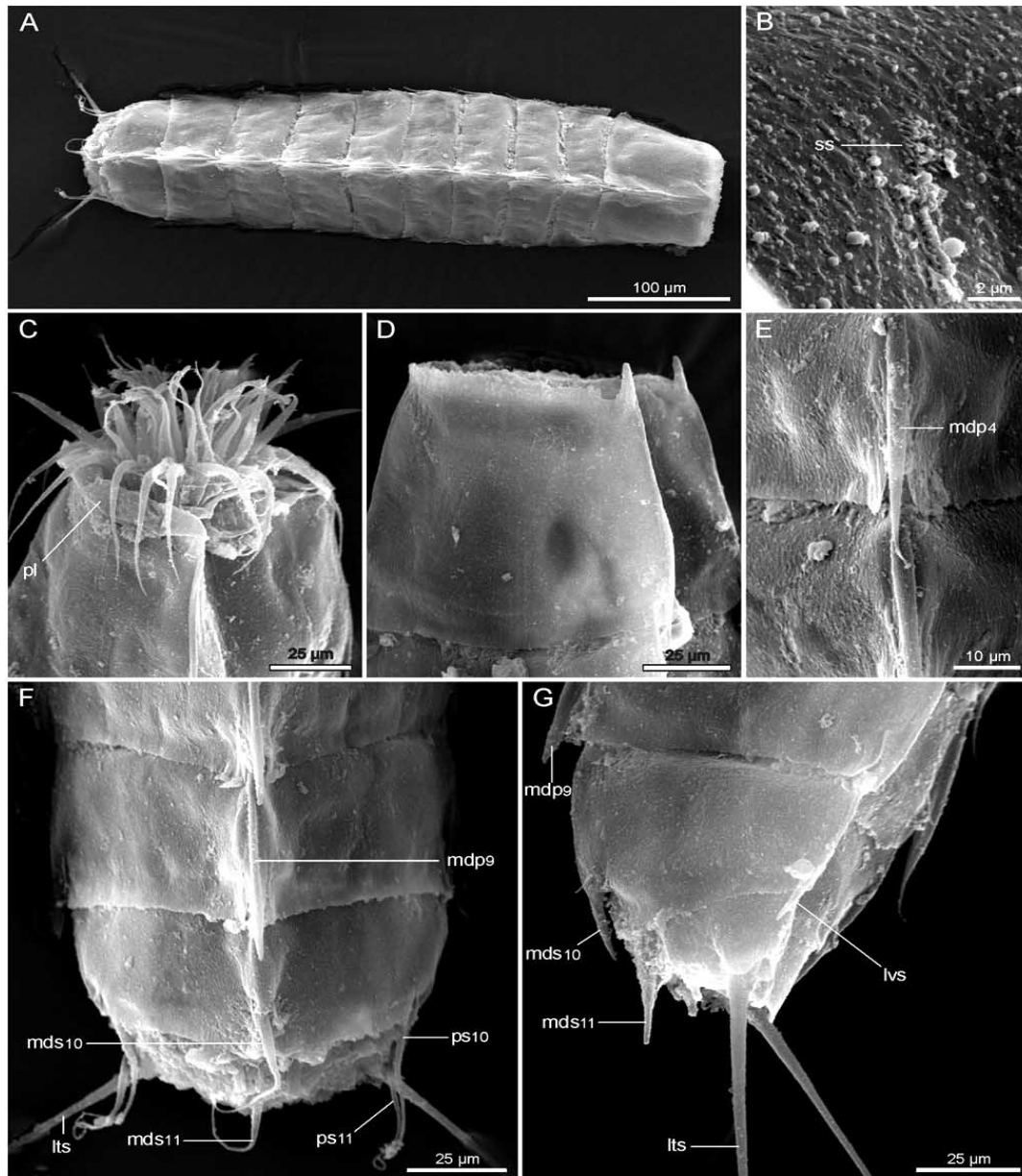


Fig. (10). Scanning electron micrographs showing cuticular head and trunk details in *Paracentrophyes* cf. *quadridentatus* from Spain. (A) Trunk of male specimen in dorsal overview. (B) Detail showing ventrolateral sensory spot on segment 4. (C) Segment 1 and partly retracted introvert, ventrolateral view. (D) Segment 1 with head completely retracted, midlateral view. (E) Middorsal processes of segments 4 and 5. (F) Segments 8 to 11 in male, dorsal view. (G) Segments 9 to 11 in female, lateral view. Abbreviations: lts, lateral terminal spine; mdp, middorsal process; mds, middorsal spine; mls, midlateral spine; pl, placid; ps, penile spine; vls, ventrolateral sensory spot. Digit after the labels refers to the segment number.

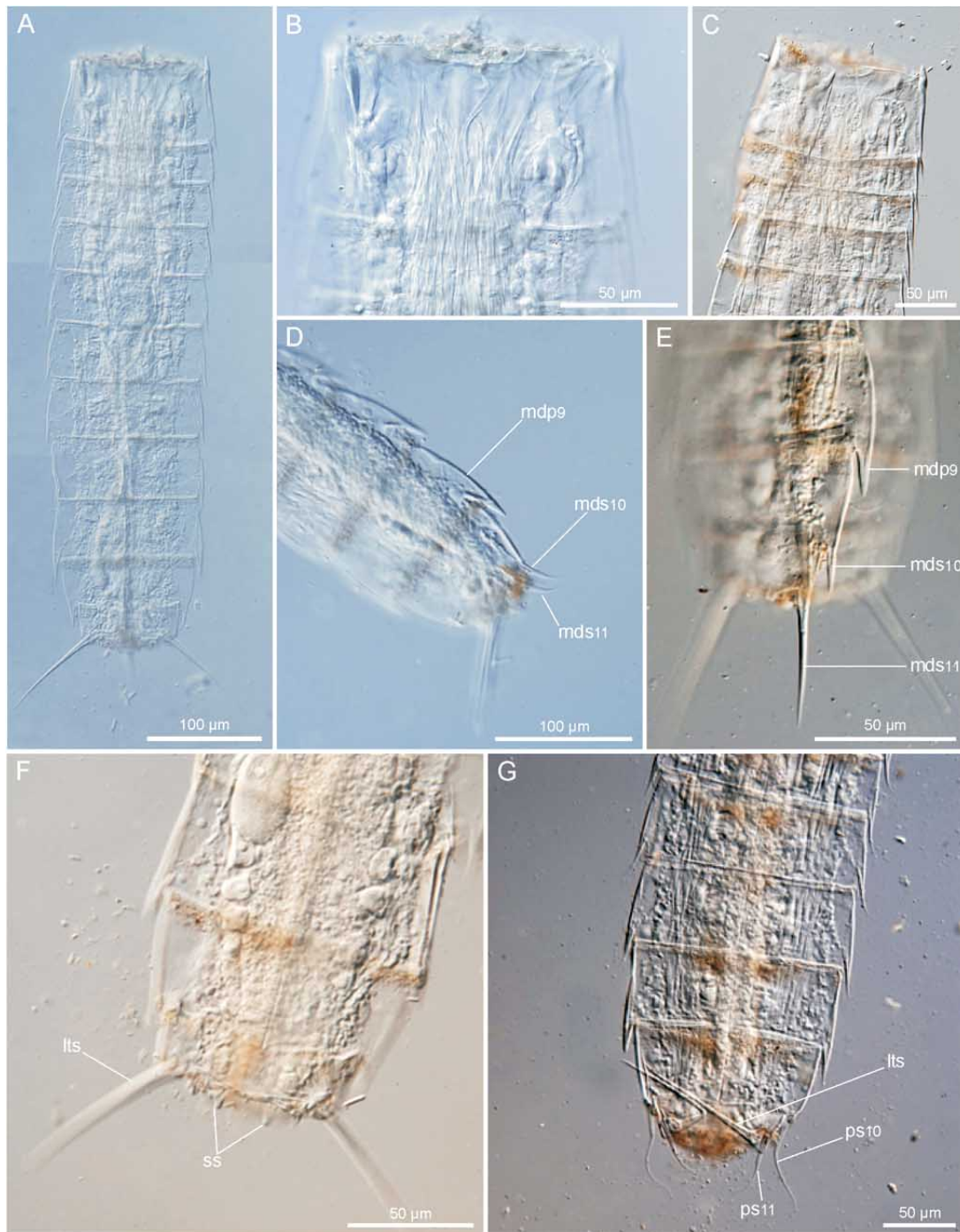


Fig. (11). Light micrographs showing cuticular and internal details in *Paracentrophyes* cf. *quadridentatus* from Spain. (A) Overview of female specimen. (B) Segment 1, ventral view. (C) Segments 1 to 5, ventrolateral view. (D) Segments 8 to 11 in male specimen, lateral view. (E) Segments 8 to 11 in female specimen, dorsal view. (F) Segments 9 to 11 in female specimen, ventral view. (G) Segments 7 to 11 in male specimen, ventral view. Abbreviations: lts, lateral terminal spine; mdp, middorsal process; mds, middorsal spine; ps, penile spine. Digit after the labels refers to the segment number.

tend to wrap halfway around the style have seven fringe tips (Fig. 9A).

The specimens are generally large, up to a trunk length of 669 µm, which constitutes the maximum trunk length of all *Paracentrophyes* spp. examined in the present study. Sternal width almost reaches its maximum around segment 4 or 5 and is retained down to segment 7 or 8.

Segment 1 has one pair of paradorsal and ventrolateral perispinal setae (Fig. 9B), whereas the following nine segments possess one pair of setae in paradorsal, paralateral and ventrolateral positions. Distribution of setae does not differ between the sexes. Middorsal spinose processes are present on segments 1 to 9, whereas the processes have been replaced by acicular spines on segments 10 and 11 (Figs. 7E,

8E, 9C). Middorsal spine on segment 10 in females is very short, not or only hardly projecting over posterior margin of segment 11 (Fig. **7E**). Middorsal spines on segments 10 and 11 are rigid in females but soft and flexible in males. Males furthermore have one pair of flexible penile spines in laterodorsal positions on segments 10 and 11 (Fig. **9C, F**). Both pairs of sternal sensory spots on segment 10 are located in a ventromedial position (Fig. **9D**). Two pairs of short subdorsal type 3 sensory spots and one pair of much longer ventromedial type 3 sensory spots are present on segment 11. The long ventromedial sensory spots in females are only slightly elevated (Fig. **7F**), whereas the male sensory spots are elevated on triangular bases with thread-like outgrowths on the outer lateral margins (Figs. **8F, 9F**). The presence of a midterminal process varies among the examined specimens. Both females mounted for LM had a minute midterminal process (Fig. **7F**), whereas its presence could not be confirmed on the female specimen mounted for SEM (Fig. **9E**). One male mounted for LM had a much more prominent midterminal process (Fig. **8F**), whereas the process could not be found on the second male mounted for LM. Both specimens had well-developed testes. The midterminal process could not be located in any of the three males mounted for SEM.

Paracentrophyes cf. quadridentatus – Spain population

Material Examined

One male (Fig. **10A, F**) and one female (Fig. **10G**) were mounted for SEM, and two females (Fig. **11A, E, F**) and one male (Fig. **11D, G**) for LM. All material is stored at the *Universidad Complutense de Madrid*, Spain, in FP's personal collection.

Brief Description

Measurements for specimens mounted for LM are given in Tables 1 and 2. See Table 4 for summary of positions of outer cuticular structures.

All specimens from the Spanish population appeared with the introvert withdrawn or only partially extended (Fig. **11C**), so no data are available for scalds in the introvert or mouth cone and oral styles.

The sizes of the specimens agree in general terms with the animals in the Faroe population and are clearly apart from those of *P. praedictus*. Sternal width almost reaches its maximum around segment 4 and is retained down to segment 7 or 8 (Table 1 and 2, but see also Fig. **11A**).

Segment arrangement and plate distribution is the same as described above for the Faroe Islands specimens. The anterior margin of segment 1 is finely denticulated with a pair of frontal projections at the tergo-sternal junction (Figs. **10D, 11B-C**). An indication of a differentiation into a two episternal and a midsternal plate is present, although very indistinct, near the anterior margin of segment 1 (Fig. **11B**). Trunk segments 1 to 10 in females and 1 to 9 in males show a broad, free posterior flap finely striated, although the very edge is quite smooth, without pectinate fringe (Fig. **10E-G**). The cuticular surface, as revealed by SEM, do not show hairs arranged in distinct patterns. Hairs are instead regularly distributed over the surface. The hairs are minute, pointed scales not detached from the surface.

Presence and distribution of perispinal setae are the same as described for the Faroe specimens. Distribution of setae does not differ between the sexes. Middorsal spinose processes are present on segments 1 to 9 in both sexes, whereas in females have rigid, acicular spines on segments 10 and 11 (Figs. **10G, 11E**), and males longer and more flexible spines (Figs. **10A, F, 11D, G**). Males furthermore have one pair of laterodorsal penile spines on segments 10 and segment 11 (Figs. **10F, 11G**). Sensory spots are inconspicuous and difficult to locate even with SEM (Fig. **10B**). A midterminal process is present in all studied individuals of both sexes, although it is clearly smaller and very short in females.

DISCUSSION

Meristic and Previously Proposed Diagnostic Characters for *Paracentrophyes*

The three currently described species of *Paracentrophyes* are not easily distinguished, and the two populations of *P. cf. quadridentatus* from Spain and the Faroe Islands add further complexity to the taxonomy of the genus. Due to the somehow superficial description of *P. quadridentatus* and

Table 5. Summary of Differences and Key Characters Among the Examined Species of *Paracentrophyes*. Important or Unique Diagnostic States are Boldfaced

	1	2	3	4	5	6	7	8	9	10	11
<i>P. praedictus</i>	12 (large), 8 (small)	1	2	PL VL	PD PL	VL VM	VM	No	Yes	No	Yes
<i>P. quadridentatus</i>	?	1	?	At least PL	At least VL	?	?	No	No	Yes	No
<i>P. cf. quadridentatus</i> (Spain)	?	0	1	PD PL VL	PD LV VL	?	?	No	?	Yes	Yes
<i>P. cf. quadridentatus</i> (Faroe Isl.)	9 (large), 7 (small)	0	1	PD PL VL	PD PL VL	VM VM	VM VM	No	Yes	Yes (very short)	In 1 spec.
<i>P. anurus</i> nov. sp.	5-7 (large), 10-12 (small)	1	1	No	No	VL VM	VL VM	Yes	No	No	No (ss type 3)

Characters: 1: Number of fringe tips on large and small outer oral styles. 2: Number of paralateral perispinal setae on segment 1. 3: Number of ventrolateral perispinal setae on segment 1. 4: Occurrence and position of perispinal setae on segment 10 in females. 5: Occurrence and position of perispinal setae on segment 10 in males. 6: Occurrence and position of sensory spots on sternal plate of segment 10 in females. 7: Occurrence and position of sensory spots on sternal plate of segment 10 in males. 8: Middorsal spine on segment 10 in females extending over and beyond segment 11. 9: Ventromedial type 3 sensory spots on segment 11 in males on triangular elevation with thread-like extensions on margin. 10: Caudal process present in females. 11: Caudal process present in males. Abbreviations: PD, paradorsal; PL, paralateral; ss, sensory spot; VL, ventrolateral, VM, ventromedial.

loss of type material, the specimens from Spain and the Faroe Islands cannot with certainty be considered conspecific with *P. quadridentatus*, but with this in mind, we choose to treat them as *P. cf. quadridentatus* in the following. A general overview of selected character traits that vary among the examined species and populations is summarized in Table 5.

Based on trunk lengths only, *P. praedictus* appears to be the shortest species with sizes ranging from 332 to 503 μm , however this range overlaps with the somehow dubious trunk lengths (370 μm and 595 μm) reported for *P. quadridentatus* (see Tables 1 and 2). *Paracentrophyes anurus* sp. nov. is among the largest species within the genus (595 to 630 μm), but again, this range overlaps with the Faroese population of *P. cf. quadridentatus* (568 to 669 μm). Hence, overall trunk lengths can, at the best, only be used as a supplement with other characters.

Higgins [2] uses the combined sternal widths to distinguish between *P. praedictus* and *P. quadridentatus*, noting that the latter possess a rather constant sternal width throughout most of the trunk whereas *P. praedictus* tapers gradually along the posterior third of the trunk. New measurements made on type specimens of *P. praedictus* (see Tables 1 and 2) reveal that the sternal width reaches its maximum and stays constant from segment 4 to 6 in males and segments 5 to 8 in females. According to the measures provided by Zelinka [1], the male sternal width is constant from segment 2 to 9 and the female from segment 2 to 8. Hence, the overall trunk shape may serve as a guideline to distinguish between the two species. In females of *P. anurus* sp. nov., maximum sternal width is retained from segment 5 to 8, thus being identical with females of *P. praedictus*. In males of *P. anurus* sp. nov. it increase with only 3 μm from segment 3 to 8, and reaches its maximum in segments 7 and 8. Males and females of the Faroese population of *P. cf. quadridentatus* reach their maximum sternal widths in segments 5 to 7 and 6 to 8, respectively, whereas the Spanish population reach their maximum sternal widths in segments 4 to 8 in males and 4 to 7 in females. By including the new information from specimens collected after Higgins' [2] studies, it appears that also ranges in sternal widths show much overlap between the species and populations (see summary in Table 5), thus also this character should be used with caution.

Besides the trunk dimensions, Higgins [2] propose following characters to distinguish between *P. praedictus* and *P. quadridentatus*: Dissimilarities in differentiation into episternal and midsternal plates of sternal plate in segment 1, lack of sensory spots, and lack of midterminal process in males of *P. quadridentatus*. In this context, we would question at least two of the proposed characters. The exact differentiation of the episternal and midsternal plates in *P. quadridentatus* cannot be judged from the illustrations in Zelinka's monograph [1] alone. It should be noted, however, that only a slight indication of a midsternal plate can be observed at the anterior margin in the Atlantic populations (Fig. 11B). We would also hesitate in concluding that *P. quadridentatus* does not possess any sensory spots at all. It seems more likely that Zelinka [1] simply left out this information, or was unable to see them. The latter is a possible explanation if his specimens resemble those from

the Spanish population, as their sensory spots are difficult to discern, even with SEM (Fig. 10B). This leaves the occurrence of the midterminal process as the only diagnostic trait. This character will be discussed further below.

Diagnostic Characters for Species of *Paracentrophyes*

Considering the limited amount of information about morphological and potential diagnostic characters for *P. quadridentatus*, we will, in the following, mainly focus on *P. praedictus*, *P. anurus* sp. nov. and the two populations of *P. cf. quadridentatus* from the Atlantic. A detailed comparison of the species reveals that they differ at several points (see Table 5), even though most differences regard minor, somehow subtle details. Unique characters for *P. anurus* sp. nov. include the complete absence of setae on segment 10, the long middorsal spine on segment 10 in females that extends considerably over the posterior margin of the terminal segment, and the midterminal type 3 sensory spot found in males. All three characters are visualized relatively easily, and make it fairly easy to discriminate *P. anurus* sp. nov. from other species. Male specimens of *P. praedictus* can be recognized by having only a single sensory spot on each sternal plate of segment 10, opposed to two sensory spots in all other examined species. However, the best diagnostic character that relate to both male and female specimens of *P. praedictus* is the presence of two pairs of ventrolateral perispinal setae on segment 1. Both *P. anurus* sp. nov. and the examined specimens of *P. cf. quadridentatus* showed only one pair of setae in this position.

Other potentially diagnostic characters concern details on the outer oral styles and the midterminal process. During SEM examinations of *P. anurus* sp. nov. and *P. cf. quadridentatus* (Faroe Islands population), and examinations of SEM photos showing the detailed head morphology in *P. praedictus* [2] it was noted that all species possess a small fringe basally on the outer oral styles, but that the appearance and number of fringe tips showed interspecific variation. *Paracentrophyes praedictus* and *P. cf. quadridentatus* (Faroe Islands population) showed twelve and nine (Fig. 9A) fringe tips, respectively, at the bases of the large oral styles, whereas *P. anurus* sp. nov. showed only five to seven (Fig. 4B). Contrarily, *P. anurus* sp. nov. showed more fringe tips, ten to twelve, around the smaller oral styles, whereas *P. praedictus* and *P. cf. quadridentatus* showed only eight and seven, respectively. Further examinations are required to determine whether this character is constant within each species, but it could be potentially species diagnostic.

Another interesting, and potentially diagnostic character, relates to the development of the midterminal process on segment 11. Higgins [2] originally described the *P. praedictus* male as possessing a flexible middorsal spine and a short midterminal spine or process, whereas he misinterpreted the female middorsal spine as being midterminal, and hence analogous with the short midterminal process in the male. However, the long, spinous appendage found on segment 11 in females of all examined species is clearly dorsal, rather than midterminal and should accordingly be referred to as a middorsal spine. This conclusion is confirmed by the presence of both middorsal spine and midterminal process in female specimens of *P.*

quadridentatus [1] and *P. cf. quadridentatus* from the two Atlantic populations (Fig. 7E-F).

The occurrence of a midterminal process related to the sex shows variation among the examined species, and it could represent another species diagnostic trait. In *P. praedictus* the midterminal process is present in males only [2], whereas Zelinka [1] describes it as being present in only females of *P. quadridentatus*. In the Spanish population of *P. cf. quadridentatus* both males and females have a midterminal process, whereas Faroe Islands included specimens of both sexes with and other without the process. Based on the apparently consistent occurrence of the midterminal process in *P. praedictus* and its complete absence in *P. anurus* sp. nov., the character obviously has some potential as being species diagnostic, but the more inconsistent occurrence among specimens of *P. cf. quadridentatus* stresses that it needs to be further explored.

Current Taxonomic Status of *Paracentrophyes*

Currently, three valid species, *P. quadridentatus*, *P. praedictus* and *P. anurus* sp. nov., can be assigned to the genus *Paracentrophyes*. As discussed above, the two latter species can be considered as well-defined, whereas *P. quadridentatus* is in urgent need of a redescription. Due to the missing information about this species, it is currently not possible to determine whether the specimens of the two Atlantic populations are conspecific with *P. quadridentatus* or if they represent one, or less probably, two distinct species. Based on the apparent presence of a midterminal process in females, we tentatively consider the Atlantic specimens as conspecific with *P. quadridentatus* but would like to stress that this assignment is not conclusive. If it is so, those populations constitute the first report for the species in the Atlantic Ocean. Future studies on the genus should focus on collection and redescription of *P. quadridentatus* from its

type locality in the Bay of Naples, and molecular characterization of the known species and populations.

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