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Freshwater cyclopoids (Crustacea: Copepoda) from the Socotra Archipelago, Yemen, with description of a new species of *Bryocyclops*

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Abstract: The cyclopoid copepods of north-eastern Socotra Island were studied and nine species in seven genera were identified. *Halicyclops soqotranus* is the first copepod ever to be recorded from Samha and Abd al-Kuri islands. *Cryptocyclops linjanticus* Kiefer, 1928 and *Microcyclops davidi* (Chappuis, 1922) are first records from Socotra Island. Data on morphological variability of the latter species are presented. A cavernicolous species, *Bryocyclops soqotraensis* n. sp., is described, illustrated and its affinities are briefly discussed.

سيلوسكوبيات المياه العذبة (القشريات: مجدافيات الأرجل) من أرخبيل سوقطرة، اليمن، مع وصف لنوع جديد من الجنس *Bryocyclops*

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خلاصة: تم دراسة سيلوسكوبيات مجدافية الأرجل من شمال شرقي جزيرة سوقطرة. تم تعريف تسعة أنواع تقع ضمن سبعة أجناس. يعتبر النوع *Halicyclops soqotranus* التسجيل الأول لمجدافيات الأرجل من جزيرتي عبد الكوري وسمحة. تم تسجيل النوعين *Cryptocyclops linjanticus* و *Microcyclops davidi* لأول مرة من جزيرة سوقطرة. كذلك تم تقديم نتائج حول الفروقات الشكلية للنوعين المذكورين سابقاً. تم وصف النوع *Bryocyclops soqotraensis* الذي يعيش في الكهوف وعمل رسوم توضيحيه له وتقديم مناقشة موجزة لصلاته بالأنواع الاخرى.

INTRODUCTION

Seven species of Cyclopoida were known from the island of Socotra before the present study (Baribwegure & Dumont 2000). As a result of the long period of isolation of the island from mainland Africa and Arabia and the relatively small risk of contamination of its aquatic fauna by humans, three of the species found were new to science. In this article, we present additional information on the cyclopoid copepods of this island, based on a collection made in 1999.

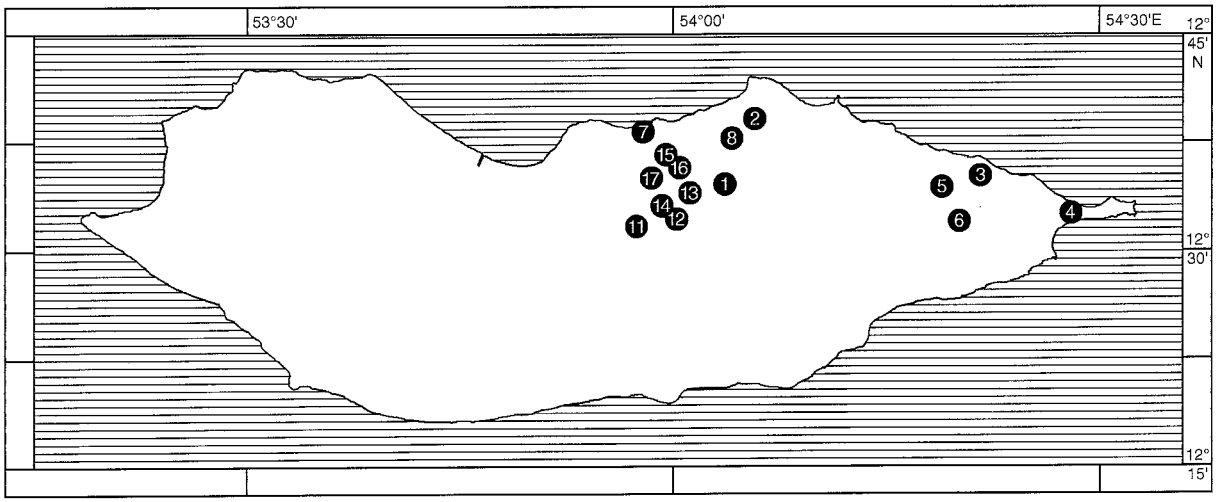


Fig. 1: Map of localities sampled. Locality numbers refer to the information given in Table 1.

MATERIALS AND METHODS

All specimens were collected by K. Van Damme. A list of samples, dates and localities in which copepods were found, together with a list of the species identified, is given in Table 1 and shown in Figure 1. Samples were collected from the north-east sector of the island, using a 100 µm mesh plankton net, and preserved in 4 % formalin immediately upon collection. Coordinates, specific conductance and pH were determined in the field, using a Garmin GPS 12XL (FOM 14-20 m), an AquaLytic L17 Bischof (Vel) conductivity meter and a WTW pH-meter, respectively. Specimens were dissected in glycerine, mounted on slides and examined under an Olympus U-DA microscope using a 100 × / 1.25 oil immersion objective adjusted for phase contrast and WH 10 × / 22 oculars for the resolution of fine detail at a magnification of 10 × 100. All drawings were made under oil immersion using a camera lucida.

Abbreviations:

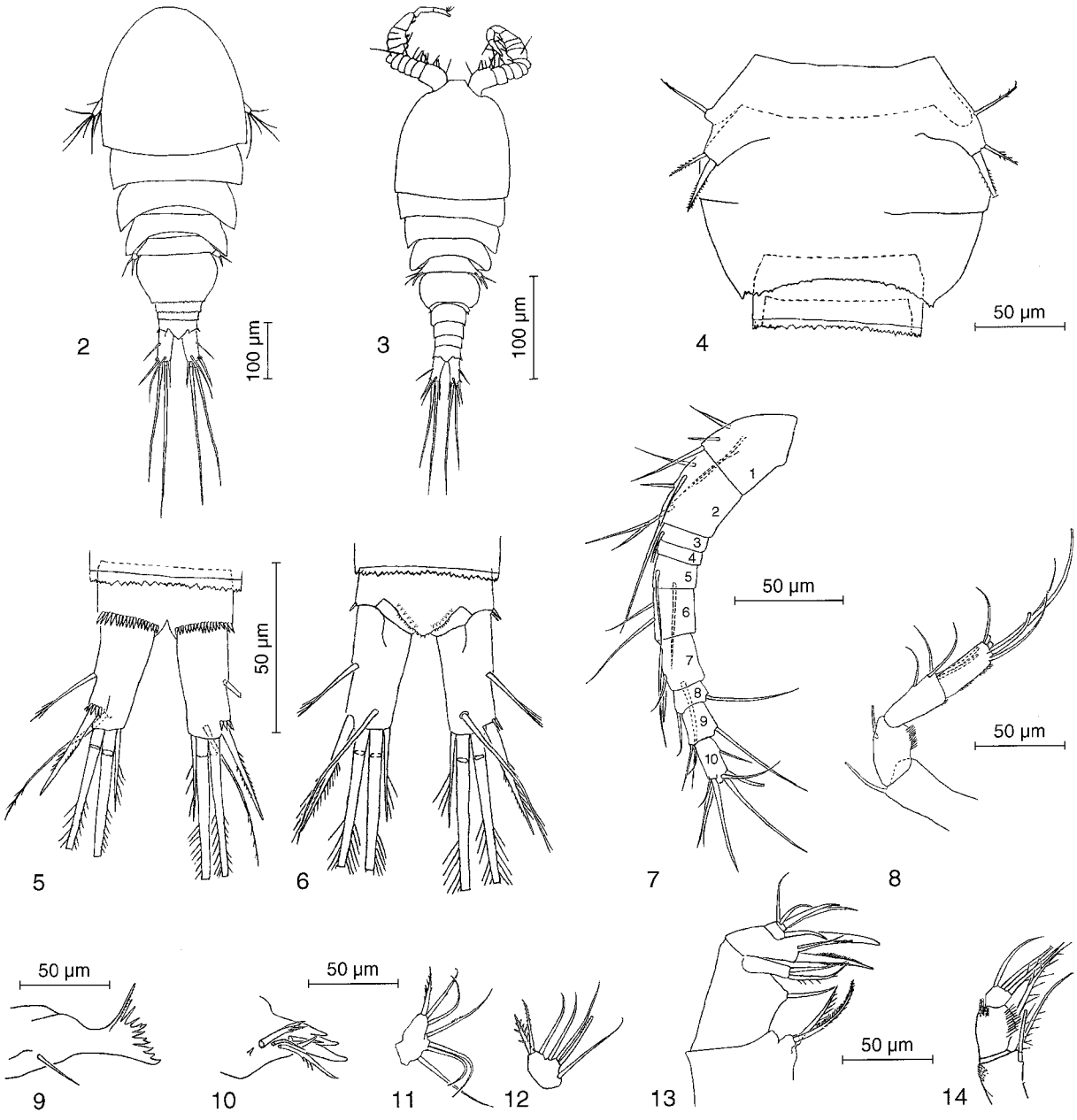
Enp	Endopodite
Exp	Exopodite
KBIN	Koninklijk Belgisch Instituut voor Natuurwetenschappen, Brussels
NHCY	Natural History Collection Yemen
P1-P6	Trunk limbs 1-6

SPECIES ACCOUNT

Nine species were recorded (Table 1), bringing the total known from Socotra and other islands of the archipelago to 11. These include one species new to science, herein described, and two relatively little-known species worthy of some comment.

Table 1: List of species recorded at each locality sampled by K. Van Damme. Cond. = Conductivity [µS cm^{-1}].

No.	Locality	Coordinates	Altitude	Sampling date	Cond.	pH	Taxa
1	Adho di Melho, Hagghier Mountains, spring	12°34.562'N 54°02.910'E	950 m	03.02.1999	680	7.8	*Paracyclops fimbriatus*
2	On the road from Hadibo to Hoq, close to spring of Ayn Fasr; shallow eutrophic stream	12°38.761'N 54°05.294'E	45 m	04.02.1999			*Cryptocyclops linjanticus*
3	Inside Hoq Cave; small waterholes	12°35.366'N 54°51.161'E	450 m	05.02.1999	1800	8.2	*Bryocyclops soqotraensis*
4	Stream emerging from NE plateau. Some young marine fish present. Fikhah spring	12°32.971'N 54°27.568'E	5 m	06.02.1999	2100	7.8	*Cryptocyclops linjanticus*
5	NE (Hamaderoh) plateau; water well	12°34.573'N 54°18.369'E	500 m	07.02.1999	2200	7.6	*Paracyclops fimbriatus*
6	On the way to Kilisan; eutrophic cattle drinking pool	12°32.152'N 54°19.689'E	500 m	09.02.1999	1400	9.0	*Cryptocyclops linjanticus* *Mesocyclops wraniki*
7	On the way from Hadibo to the airport; coastal drinking wells	12°38.248'N 53°57.453'E	0 m	12.02.1999	4200	7.5	*Halicyclops soqotranus* *Cryptocyclops linjanticus* *Mesocyclops wraniki*
8	Wadi Daneghan, stream close to "Sultan's Palace"	12°36.977'N 54°03.784'E	150 m	13.02.1999	420	6.7	*Microcyclops pachyspina* *Microcyclops davidi* *Cryptocyclops linjanticus*
9	Samha Island; waterhole	12°09.955'N 53°01.906'E	210 m	16.02.1999	4000	7.3	*Halicyclops soqotranus*
10	Abd al-Kuri Island; coastal drinking well	12°12.004'N 52°15.588'E	10 m	18.02.1999	7000	7.9	*Halicyclops soqotranus*
11	Deksam, close to village "Grunhin"; small hypertrophic lake used as drinking pool	12°31.394'N 53°57.240'E	950 m	18.02.1999	2000	7.8	*Mesocyclops aspericornis*
12	Deksam Plateau; *Juncus*-dominated marsh	12°32.436'N 53°59.723'E	1010 m	22.02.1999	1800	6.7	*Tropocyclops confinis* *Mesocyclops wraniki*
13	Hagghier mountains; oligotrophic stream	12°33.398'N 54°00.567'E	1200 m	23.02.1999	3200	7.2	*Paracyclops fimbriatus* *Microcyclops pachyspina* *Mesocyclops wraniki*
14	Deksam; slow-running shallow stream	12°32.549'N 53°59.581'E	950 m	24.02.1999	3200	7.6	*Tropocyclops confinis* *Paracyclops fimbriatus* *Cryptocyclops linjanticus* *Mesocyclops aspericornis*
15	Wadi Ayhaft; littoral of eutrophic stream	12°36.284'N 53°59.485'E	285 m	02.03.1999	400	7.2	*Cryptocyclops linjanticus*
16	Wadi Ayhaft; oligotrophic spring on hillside, full of young *Socotrapotamon socotrensis*	12°35.910'N 53°59.514'E	300 m	02.03.1999	600	7.6	*Paracyclops fimbriatus* *Microcyclops davidi* *Microcyclops pachyspina*
17	Rewgid; waterhole inside rocks	12°34.926'N 53°58.041'E	685 m	03.03.1999	200	7.2	*Mesocyclops wraniki*



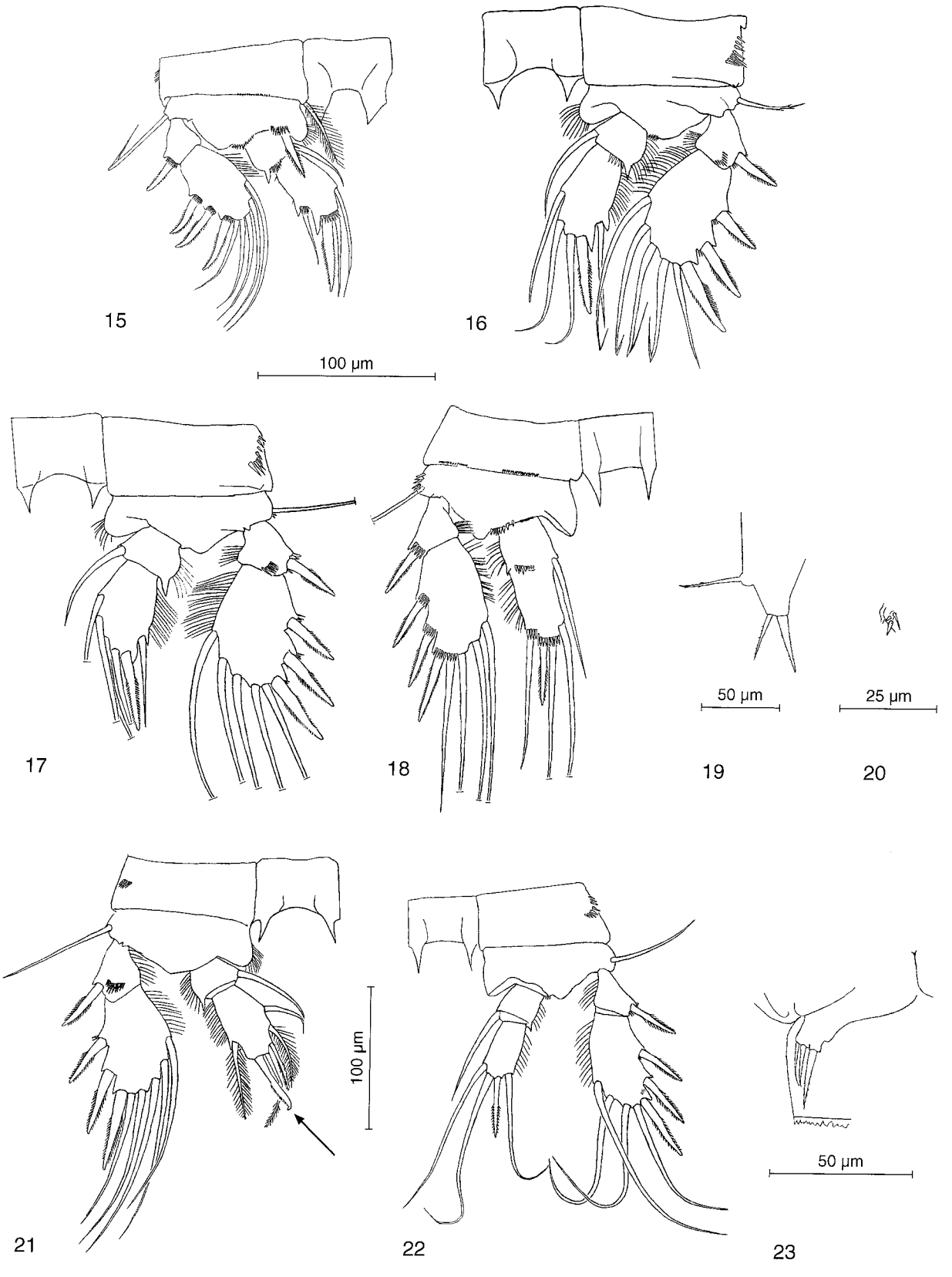
Figs 2-14: *Bryocyclops soqotraensis* n. sp. **2:** Habitus of ♀ holotype. **3:** Habitus of ♂ specimen. **4-14:** Characters of ♀ holotype. **4:** Last thoracic and genital somites. **5:** Furcal ramus in ventral view. **6:** Furcal ramus in dorsal view. **7:** Antennule. **8:** Antenna. **9:** Mandible. **10:** Maxillule. **11-12:** Maxillulary palp. **13:** Maxilla. **14:** Maxilliped.

Bryocyclops soqotraensis n. sp. Figs 2-23

Holotype: ♀, dissected, mounted in glycerine on slide, Yemen, Socotra Island, Hoq Cave, 12°35.366'N 54°51.161'E, 450 m, small waterholes, 5.II.1999, K. Van Damme, KBIN IG 28.796. — Paratypes: Yemen, Socotra: 1 ♂, 1 ♀, dissected, same data as holotype, KBIN COP 4492-4495. Two non-type specimens are to be deposited in the NHCY.

Type locality: A pool inside Hoq Cave, Socotra Island, Yemen.

Differential diagnosis: *Bryocyclops soqotraensis* is easily differentiated from all its congeners by its 10-segmented antennules (versus 11 in all other known species) and by the fine marginal denticulation and the second, internal row of spines of its relatively small anal opercu-



Figs 15-23: *Bryocyclops soqotraensis* n. sp. **15-20:** Trunk limbs of ♀. **15:** P1. **16:** P2. **17:** P3. **18:** P4. **19:** P5. **20:** P6. **21-23:** Trunk limbs of ♂. **21:** P3. **22:** P4. **23:** P6.

lum. The endopodites of the trunk limbs (P1-P4) are smaller than the exopodites, but relatively larger than in most other species. The spine on the tip of the endopodite of P3 in the male is finely denticulated along the apical half of its external border, but not swollen in its middle as in most other species, e.g. *B. phyllopus* Kiefer, 1935, *B. campaneri* Rocha & Bjornberg, 1987 and *B. caroli* Bjornberg, 1985 (see ROCHA & BJORNBERG 1987).

Description of female holotype: Body length 745 µm in holotype, 706 µm in paratype. Cephalothorax oval anteriorly, about same length as width (Fig. 2), glabrous, without refractile parts and with no sign of a posterior 'scar'. Pediger 2-4 without hyaline frill. Genital double somite strongly developed (Fig. 4). Posterior borders of genital double somite and two subsequent somites with irregularly dentate hyaline frill. Distal margin of anal somite bearing spinules ventrally (Fig. 5). No pseudosomite between pediger 5 and genital double somite. Anal operculum triangular, prominent (Fig. 6), but its tip not extending markedly beyond the base of the furcal rami, operculum finely denticulated on its margins, with a second row of denticles on its lower surface.

Furcal rami 2.70 times longer than wide (paratype: 2.45 times), slightly divergent (Figs 5-6). Lateral seta inserted at middle of ramus. Insertion of outermost apical furcal seta provided with spinules. Innermost apical furcal seta shorter than outermost and dorsal setae and furcal ramus.

Antennules 10-segmented (Fig. 7), not reaching posterior margin of cephalothorax. Setal formula, from base to tip: 6, 7, 2, 1, 2, 3, 2+A, 2, 2+A, 7+A (A = aesthetasc).

Basipodite of antenna bearing only one seta, second segment of endopodite with five setae (Fig. 8).

Mandible, maxillule, maxilla and maxilliped as in Figs 9-14.

P1-P4 with both rami bisegmented, except for Enp P4, with one segment (Figs 15-18). Endopodites smaller than exopodites, but only slightly. Connecting plates of P1-P4 with pair of long dentiform processes. Coxopodite P1 with seta on inner corner, coxopodites P2-P4 without seta. Basipodite P1 with inner spine surrounded by row of spinules. Inner margins of basipodites P1-P3 with setules, inner margin of basipodite P4 without setules. Exp 2 of P1-P4 with spine formula 3.3.3.3 and seta formula 5.5.5.4. Enp 2 of P1-P3 with spine formula 1.1.1 and seta formula 3.4.5. Enp P4 bearing one spine and four setae.

Basal segment of P5 represented by one seta, distal segment reduced to small protuberance with inner spine longer than outer seta (Fig. 19). P6 consisting of two spinules and one seta (Fig. 20).

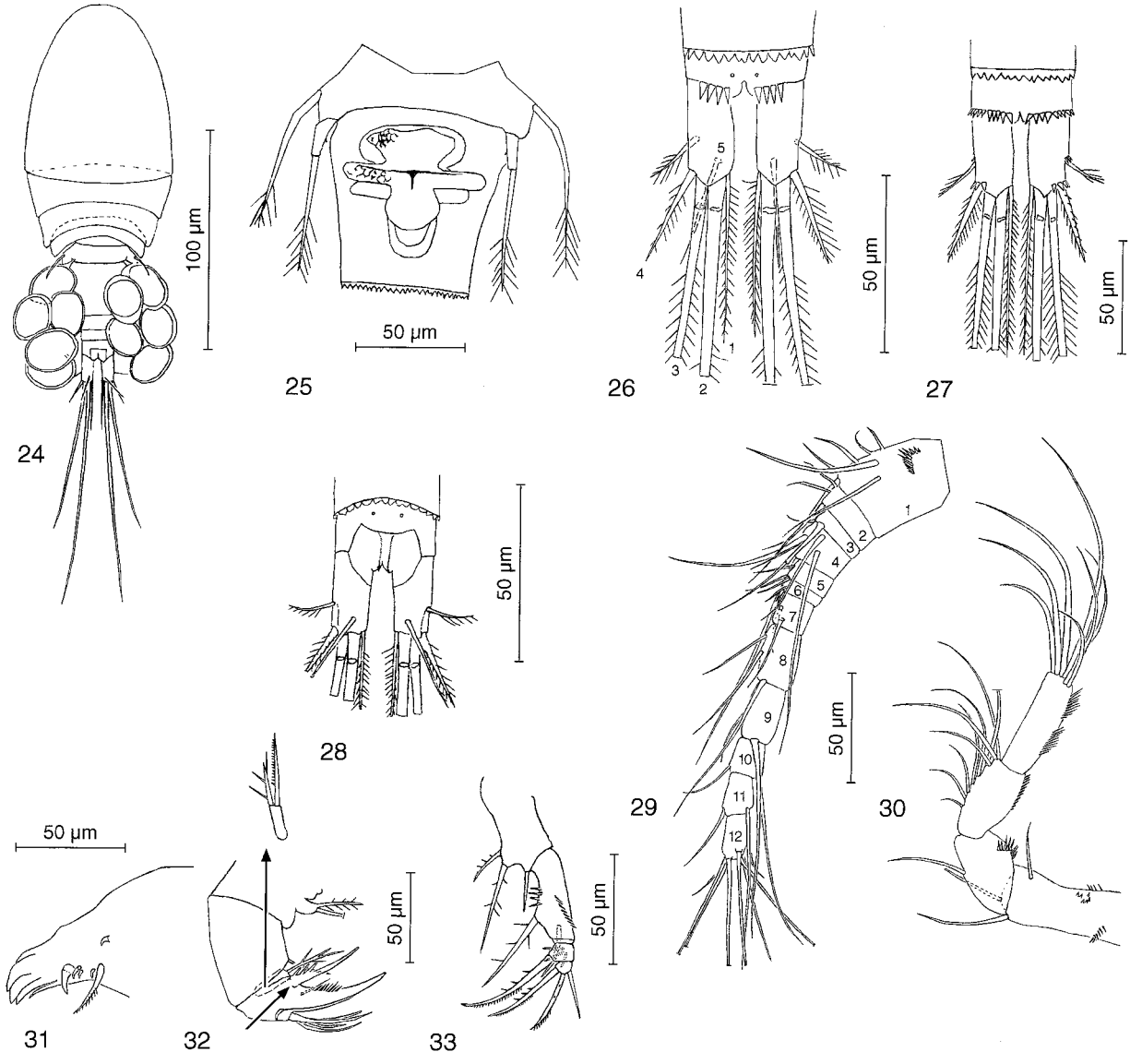
Description of male: Body length 745 µm. Lateral wings of four thoracic somites rounded (Fig. 3). P3 and P4 dimorphic as follows: Enp 2 of P3 with modified apical spine (Fig. 21), Enp P4 bisegmented (Fig. 22). Ventral spine of P6 longer than dorsal and medial setae (Fig. 23).

Microcyclops davidi (Chappuis, 1922) Figs 24-38

Cyclops davidi Chappuis, 1922. — Rev. Suisse Zool. 29 (5): 168-176.

Specimens examined: Yemen, Socotra: 2 ♀♀, Wadi Daneghan, 12°36.977'N 54°03.784'E, 150 m, stream close to "Sultan's Palace", 13.II.1999, K. Van Damme; 3 ♂♂, 4 ♀♀, Wadi Ayhaft, 12°35.910'N 53°59.514'E, 300 m, oligotrophic spring on hillside, full of young *Socotrapotamon socotrensis*, 2.III.1999, K. Van Damme. 1 ♂ and 3 ♀♀ from Ayhaft, mounted on slide, will be deposited in the NHCY.

Description of female: Body length 640-760 µm. Body widest at the level of the cephalothorax (Fig. 24). Lateral margins of last thoracic somite without ornamentation. Genital double somite expanded proximally (Fig. 25). Caudal margin of last urosomite ventrally bearing four spinules near base of each furcal rami (Fig. 26). Anal operculum slightly convex (Fig. 28).



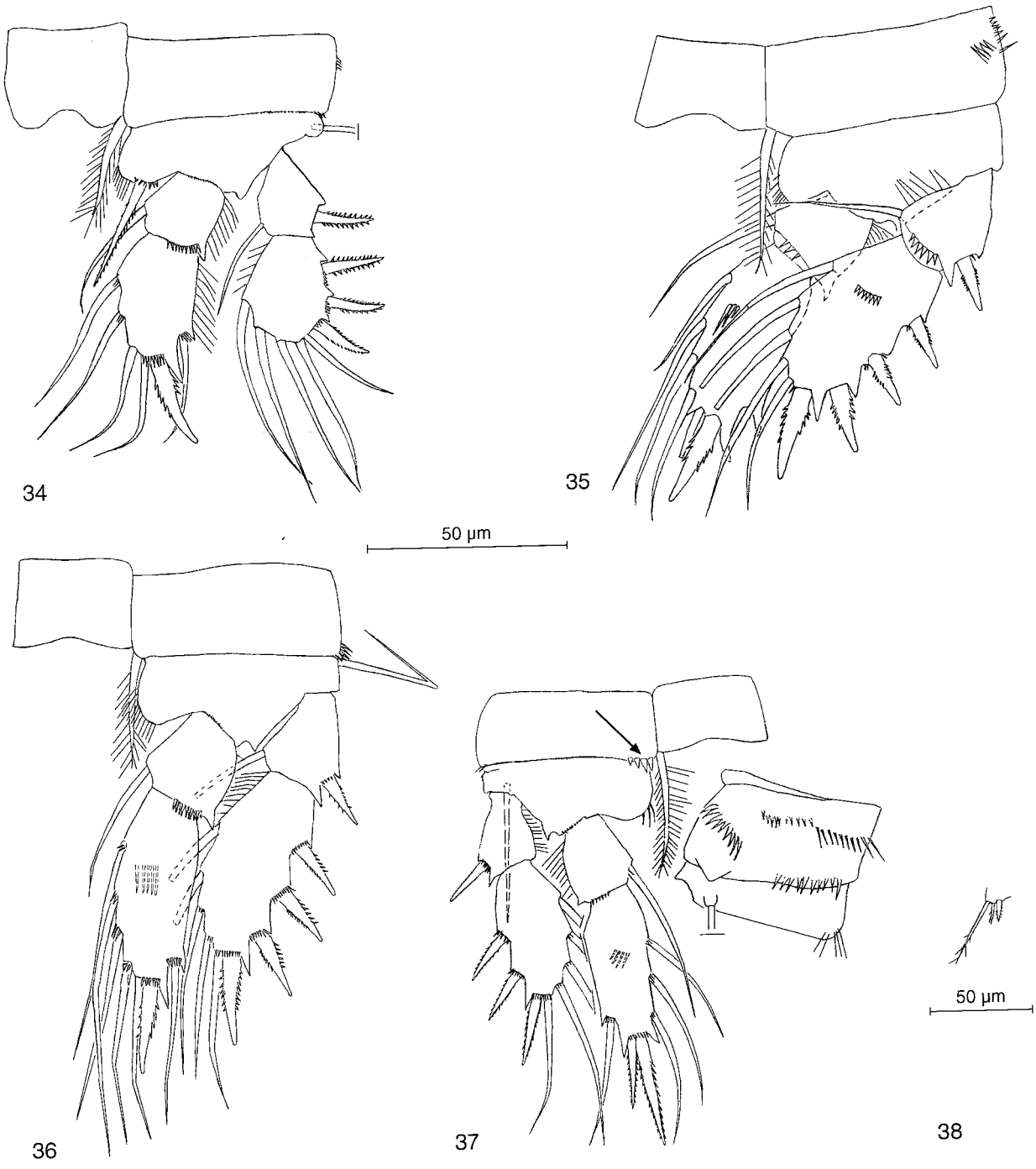
Figs 24-33: *Microcyclops davidi* (Chappuis, 1922). **24:** Habitus of ♀ specimen. **25:** Genital double somite. **26:** Furcal ramus of ♀ in ventral view. **27:** Furcal ramus of ♂ in ventral view. **28:** Furcal ramus of ♀ in dorsal view. **29:** Antennule. **30:** Antenna. **31:** Maxillule. **32:** Maxilla. **33:** Maxilliped.

Furcal rami with smooth inner margins (Fig. 26), 2.25-2.55 times as long as wide. Insertions of lateral and outermost apical furcal setae not provided with spinules. All setae with homonomous feathering. Innermost apical seta markedly longer than furcal rami and outermost apical and dorsal furcal setae (Table 2, Fig. 26).

Antennule composed of 12 segments (Fig. 29). Enp 2 of antenna bearing nine setae (Fig. 30).

Maxillule, maxilla and maxilliped as in Figs 31-33. Inner claw-like seta of base of maxilla with 3-4 teeth (Fig. 32, arrow).

P1-P4 bisegmented (Figs 34-37). Spine formula 3.4.4.3, seta formula 5.5.5.5. Connecting plates without ornamentation. Inner distal corner of P4 coxa with row of four spinules on frontal side (Fig. 37, arrow). Inner margins of base of P1-P3 with setules, that of P4 with spinules. Inner margin of base of P1 with long spine reaching middle of Enp 2 of P1. Enp 2 of P4 2.20-2.60 times



Figs 34-38: *Microcyclops davidi* (Chappuis, 1922). 34-37: Trunk limbs of ♀. 34: P1. 35: P2. 36: P3. 37: P4. 38: Trunk limb P6 of ♂.

as long as wide; inner apical spine shorter than segment and 1.35-1.50 times longer than outer spine.

Free segment of P5 2.7-3.0 times as long as wide, bearing apical seta and tiny inner denticle at middle part of segment (Fig. 26).

Description of male: Body length 610 µm. Morphology of legs and furcal rami similar to that of female, but insertions of lateral and outermost apical furcal setae provided with spinules (Fig. 27). Caudal margin of anal somite bearing spinules on ventral, dorsal and lateral sides.

Table 2: Measurements of females of *Microcyclops davidi* (Chappuis, 1922) and *Microcyclops pachyspina* Lindberg, 1937. Seta numbers as in Fig. 26.

	Microcyclops davidi			*Microcyclops pachyspina*			
	Wadi Daneghan (1999) n = 2	Wadi Ayhaft (1999) n = 4		Wadi Ayhaft (1999) n = 5		Wadi Go'oh (1996) n = 5	
	Range	Range	Mean	Range	Mean	Range	Mean
Body length in μm	685-760	640-680	654	810-1000	903		
Furca length : width	2.40-2.50	2.25-2.55	2.33	3.00-3.38	3.09	2.87-3.20	3.02
Somite 1 : furca	1.69-1.77	1.50-1.77	1.58	1.10-1.18	1.14	1.10-1.15	1.12
Somite 1 : somite 2	0.20-0.22	0.19-0.23	0.21	0.20-0.20	0.20		
Somite 1 : somite 3	0.29-0.31	0.28-0.33	0.30	0.29-0.30	0.29		
Somite 1 : somite 4	1.69-1.75	1.67-1.90	1.75	1.30-1.46	1.40	1.37-1.59	1.48
Somite 1 : somite 5	1.47-1.60	1.50-1.64	1.55	1.30-1.30	1.30	1.15-1.47	1.30
Endopodite 2 of P4:							
Length : width	2.25-2.33	2.20-2.60	2.39	2.35-2.90	2.65	2.39-2.67	2.56
Internal spine length	0.78-0.80	0.75-0.87	0.80	0.55-0.62	0.60	0.61-0.68	0.65
Internal : external spine	1.48-1.50	1.36-1.50	1.44	1.47-1.78	1.65	1.79-1.84	1.81

Antennal Enp 2 with seven setae. Ventral spine of P6 about three times shorter than dorsal seta (Fig. 38).

Remarks: *Microcyclops davidi* is a tropical Afro-Asiatic species (DUSSART & DEFAYE 1985, DUSSART & FERNANDO 1985). It is very close in morphology to the Palaearctic *Microcyclops varicans* (Sars, 1863), from which it differs mainly in having shorter furcal rami and a different ornamentation of the anal somite.

Microcyclops pachyspina Lindberg, 1937

Microcyclops pachyspina Lindberg, 1937. — Rec. Indian Mus. 39: 166-176.

Specimens examined: Yemen, Socotra: 5 ♀♀, Wadi Ayhaft, 12°35.910'N 53°59.514'E, 300 m, oligotrophic spring on hillside, full of young *Socotrapotamon socotrensis*, 2.III.1999, K. Van Damme; 5 ♀♀, Wadi Go'oh, 12°32'36"N 54°10'20"E, 28.III.1996, H.J. Dumont. An equivalent number of specimens from both localities are to be deposited in the NHCY.

Microcyclops pachyspina is another common Afro-Asiatic tropical/subtropical species. It was originally described from India as *Cyclops (Microcyclops) varicans pachyspina* by LINDBERG (1937). Later, LINDBERG (1939) changed his opinion and considered this species to be identical with true *Microcyclops varicans* (Sars, 1863). However, as shown recently by BAZAROVA et al. (1998), *M. pachyspina* clearly differs from European *Microcyclops varicans* by having shorter and thicker apical spines on Enp 3 of P4, by the ornamentation of the anal somite, by the shape of P5, by the number of setae on the third segment of the antenna and by the presence of spinules near the insertion of the outermost apical furcal setae. Thus, it must be considered a separate, valid species.

Microcyclops pachyspina is close to *Microcyclops* sp. aff. *varicans* recently reported from Socotra by BARIBWEGURE & DUMONT (2000), differing mainly in the number of setae on the third segment of the antenna (six in *M. pachyspina* versus 8-9 in the species studied by BARIBWEGURE & DUMONT 2000). Checking some additional samples collected from Socotra in March 1996 (Wadi Go'oh)

by HJD revealed *M. pachyspina* and *M. davidi* to be present here as well. Some comparative measurements of females from Wadi Ayhaft and from a sample collected in Socotra by HJD in March 1996 are presented in Table 2. They are essentially similar.

Distribution of cyclopoids across the Socotra Archipelago (Fig. 1 and Table 1)

The single most interesting record is that of a cavernicolous *Bryocyclops*. Although this genus has a few South American representatives (REID 1999), its major species richness is to be found in the Afro-Asiatic realm. It had not been recorded from the intervening Somalian-Arabic zone and therefore the current record narrows a gap in the geographic range of the genus. *Bryocyclops soqotraensis* n. sp. is a slightly aberrant representative, however, and its position relative to its congeners is somewhat obscure.

Regarding distribution of the other species, *Paracyclops fimbriatus* (Fischer, 1853) was restricted to slightly basic (pH 7.2-7.8) oligotrophic springs on the limestone plateaux; it was not found in the lower regions of the part of the island investigated (< 300 m). *Halicyclops soqotranus* Baribwegure & Dumont, 2000 was found in brackish coastal wells and is the first and only copepod recorded from Samha and Abd al-Kuri islands. *Cryptocyclops linjanticus* Kiefer, 1928 and *Mesocyclops wraniki* Baribwegure & Dumont, 2000 are common throughout the sampled region, with no clear preference for specific water types. *Microcyclops pachyspina* and *Microcyclops davidi* were found in oligotrophic streams with low conductivity. *Mesocyclops aspericornis* (Daday, 1906) and *Tropocyclops confinis* Kiefer, 1930 were only found in two locations up in the Hagghier Mountains. *Ectocyclops mozhae* Baribwegure & Dumont, 2000 is the only previously recorded species that was not collected again.

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