Neocyclops (Protoneocyclops) ferrarii, a new species of cyclopid (Copepoda: Cyclopoida) from Belize, with remarks on the morphology of the genus Neocyclops

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Abstract

Neocyclops (Protoneocyclops) ferrarii sp. n. is described from Candy's Pond, Twin Cays, Belize. It is morphologically closest to *N. (P.) wellsi* Petkovski, 1986 from Mozambique and *N. (P.) herbsti* Petkovski, 1986 from the Red Sea.

Pediger 1 in *Neocyclops* is distinct although reduced and often concealed beneath the cephalic shield. Specimens of *Neocyclops (N.) vicinus* and *N. (N.) medius* showed the same condition, warranting the supposition that the free pediger 1 is a consistent feature of the genus. The genital double somite bears a transverse cuticular thickening which apparently supports the seminal receptacle. The importance of the integumental pore patterns of the urosome and legs as useful taxonomic characters is pointed out.

Zusammenfassung

Neocyclops (Protoneocyclops) ferrarii sp. n. ist zum ersten Mal für Candy's Pond, Twin Cays, Belize beschrieben worden. Die Art ist *N. (P.) wellsi* Petkovski, 1986, aus Mosambik, und *N. (P.) herbsti* Petkovski, 1986, aus dem Roten Meer, am nächsten.

Pediger 1 in *Neocyclops* zeigt sich immer noch deutlich obwohl verkleinert und oft unter dem Kopfschild versteckt. Untersuchte Individuen von *Neocyclops (N.) vicinus* und *N. (N.) medius* zeigten dieselbe Kondition und rechtwertigen die Annahme dass der freie Pediger 1 ein beständiges Kennzeichen des Genus ist. Das doppelte Genitalsomit hat eine transversale Kutikularverdickung die offensichtlich das Receptaculum seminis stützt. Die Bedeutung des Musters der Hautporen des Hinterkörpers und der Beine als nützliche taxonomische Merkmale ist angeführt.

Introduction

The first record of the genus *Neocylops* from the Caribbean region is that of Pleşa (1973), who described *N. improvisus* from the interstitial of a sandy beach in Cuba. Subsequently, Pesce (1985) described *Neocyclops (Protoneocyclops) stocki* from Bonaire and identified specimens from San Salvador Island, Bahamas, as *Neocyclops (Neocyclops) affinis* Dussart, 1974, despite some morphological differences from the type material collected at the coast of Ethiopia. Petkovski (1986) redescribed *N. (P.) stocki* based on material from San Andrès Island and Bermuda, attributing to this species the Cuban specimens identified as *N. remanei mediterraneus* (Kiefer, 1960) by Pleşa (1981). Recently, Pesce & Galassi (1993) increased the number of species in the West Indies to seven, describing *N. (P.) geltrudeae* as a new species from Curaçao, recording *N. (N.) medius* Herbst, 1955 in Tortuga, Bonaire, Blanquilla, Los Roques, and Margarita, *N. (N.) vicinus* (Herbst, 1955) in Los Roques and Jamaica, *N. (P.) stocki* in Bonaire and Curaçao as well as communicating Fiers' record of *N. (P.) papuensis* Fiers, 1986 in the Bahamas.

Habitat

Candy's Pond, Twin Cays, is about 5 m in diameter, 2 m deep, and heavily shaded by mangroves. At the time of collecting, a sharp thermocline and halocline were present at about 20–30 cm. The upper water was 30°C, 19‰ S and the deeper water 35°C, 39‰ S. The copepods were collected above leaf litter at the bottom of the pond (F. Ferrari, pers. comm.). Accompanying species: *Apocyclops panamensis* (Marsh, 1913).
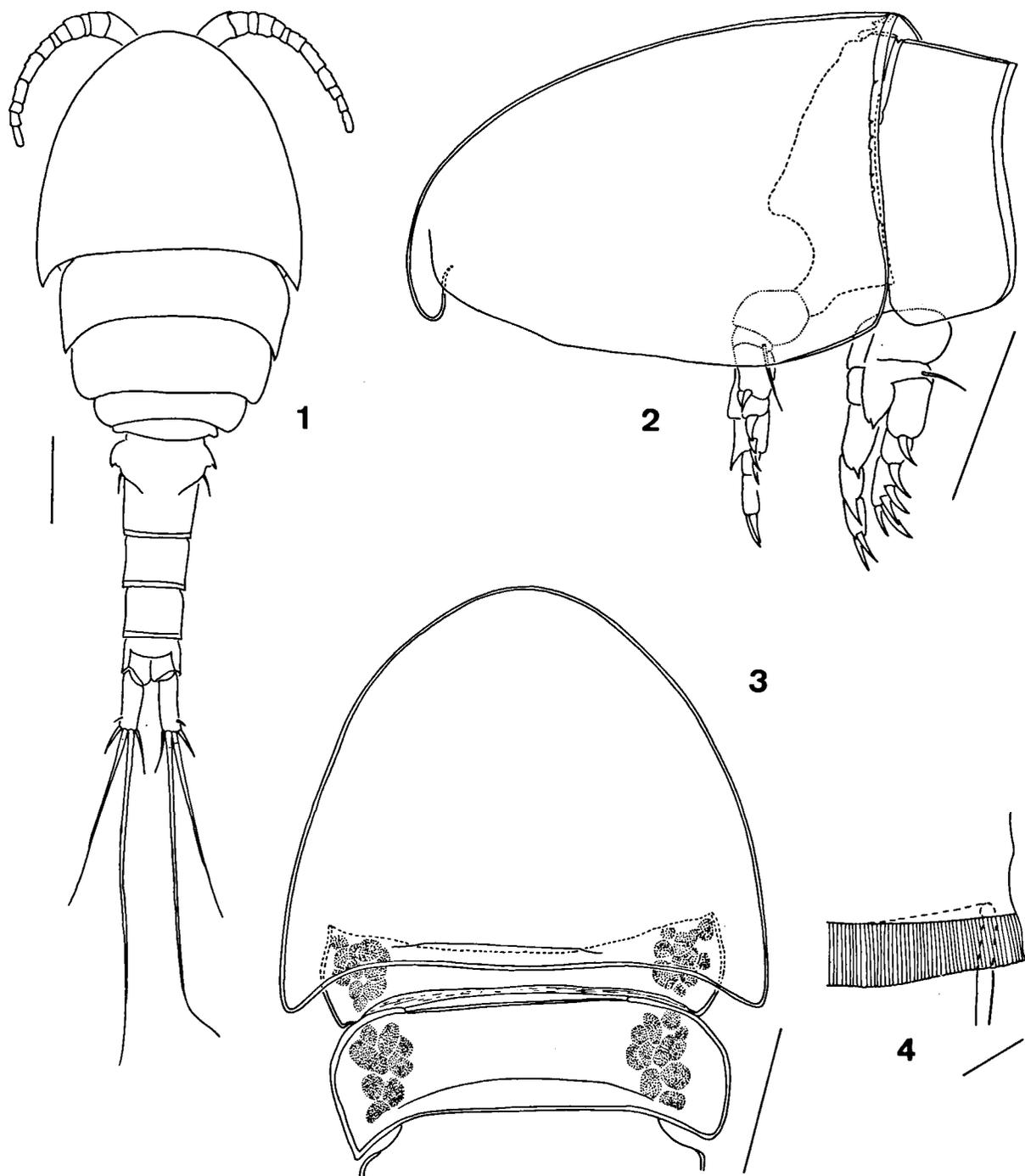
Figs. 1–4. *Neocyclops (Protoneocyclops) ferrarii* sp. n., ♀: 1, habitus, dorsal; 2, anterior part of prosome showing pediger 1 concealed beneath carapace-like extension of the cephalic shield, lateral; 3, anterior part of prosome showing pediger 1 partly exposed, dorsal (dotted areas representing muscle insertions); 4, hyaline frill of posterior border of pre-anal somite, ventral. Scale bars 100 μm (Figs. 1–3), 10 μm (Fig. 4).
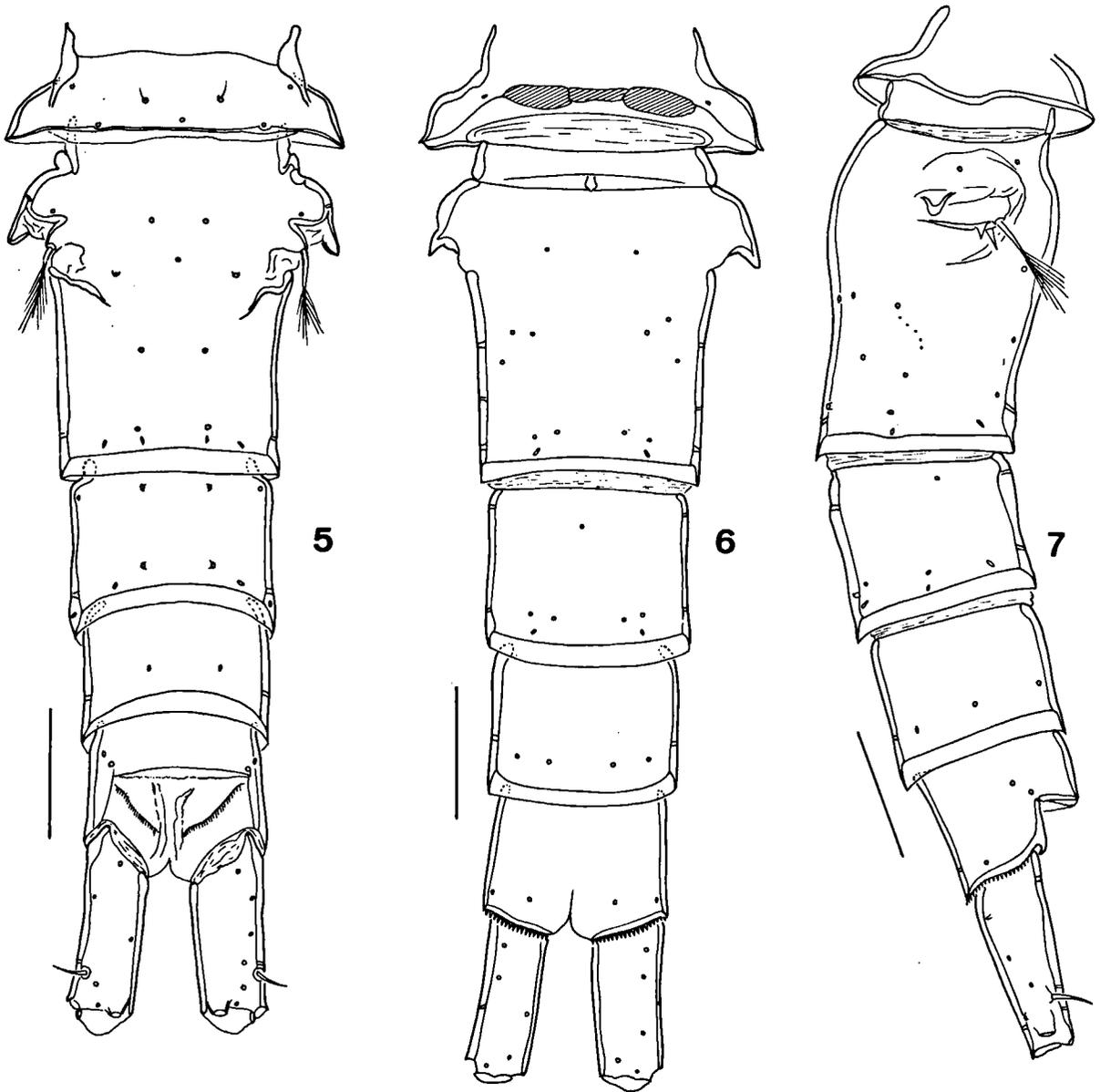
Figs. 5–7. Neocyclops (Protoneocyclops) ferrarii sp. n., ♀: 5, urosome, dorsal; 6, urosome, ventral; 7, urosome, lateral. All figures showing integumental pore patterns as visible in respective views. Scale bars 50 μm.

Methods

Whole specimens were examined in temporary lactic acid mounts. Fragments of cover glass were used to support the cover glass of the preparations. By moving the cover glass slowly and carefully by hand, the whole animal or a particular appendage was placed in different positions, making possible observation of morphological details. After examination the specimens were preserved in 70% ethanol.

The urosome integumental pore pattern was obtained from clean exoskeletons of two females found in the sample.

Dissected and intact specimens were examined for variation in the characters described.

The figures were made using an oil immersion lens and a camera lucida on a Leitz Laborlux D phase-contrast microscope.
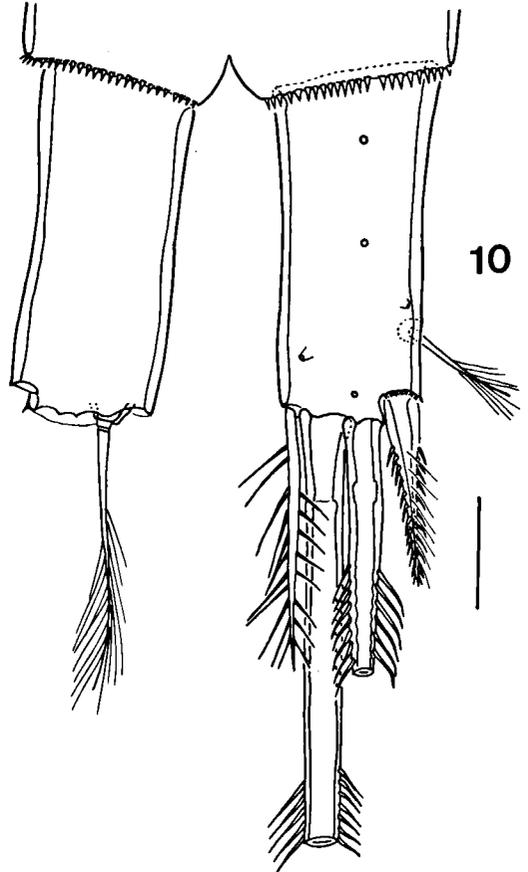
The material is deposited in the National Museum of Natural History, Smithsonian Institution, Washington (NMNH, formerly USNM) and the Museu de Zoologia of the Universidade de São Paulo, São Paulo (MZUSP).
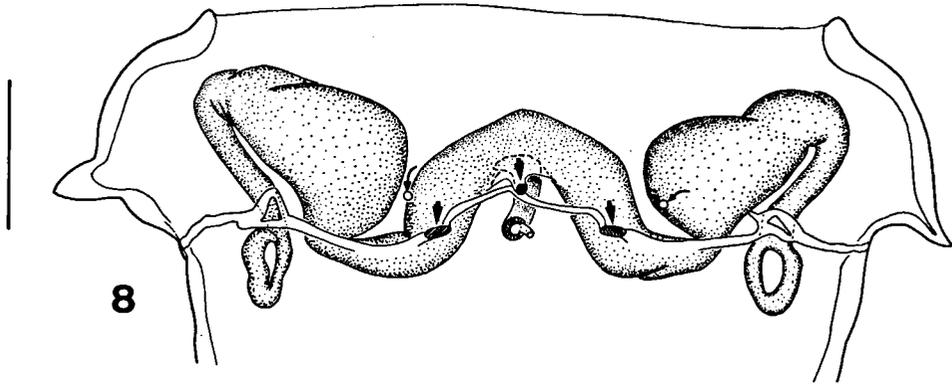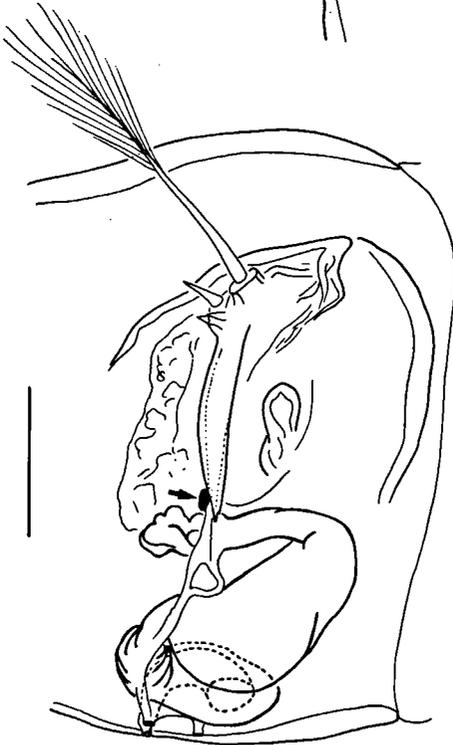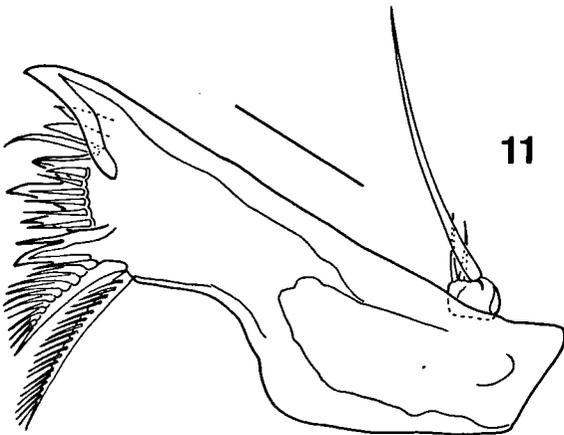
Descriptive part

Neocyclops (Protoneocyclops) ferrarii sp. n.
(Figs. 1−19)

Material examined. − Belize, 36 ♀♀, 15 ♂♂ and 24 copepodids from Candy's Pond, Twin Cays (16°50′N, 88°5′W), 3 July 1987, F.D. Ferrari coll. Female holotype (USNM 259772) and 15 paratypes (USNM 259773) in NMNH; 59 paratypes in MZUSP (coll. nr. 11571).

Description. − Female: Body length, excluding caudal setae, 635 to 860 μm ($n = 9$). Prosome little longer than urosome (1.18−1.3 : 1). First pediger narrower than second pediger and concealed beneath carapace-like extension of posterior margin of dorsal cephalic shield (Figs. 1−2); only one specimen had this somite partly exposed (Fig. 3). Hyaline fringes of posterior borders of prosomites, genital double somite and 2 subsequent urosomites striated (Fig. 4). Pore signature pattern of urosome (Figs. 5−7) consisting of circular and slit pores.

Genital double somite (Fig. 5) about as long as wide and with lateral expansions bearing spiniform projections at first third. Seminal receptacle (Fig. 8) turning backward from connection with copulatory duct, then expanding and curving onward and outward after straightening about midway along its length; short receptacle ducts present, connecting both expanded parts to dorsolateral genital antra. Transverse cuticular thickening partially fused to seminal receptacle on both sides anteriad to its straightening, linked to integument of genital double somite by 3 ventral attachment areas (straight arrows in Fig. 8) and another attachment area very near ventral tip of opercular plate of each leg 6 (arrows in Fig. 9). Copulatory area with pair of integumental pores (curved arrows in Fig. 8).

Anal somite (Figs. 5−7) bearing ventrolateral row of spinules along posterior margin. Anal operculum consisting of narrow, finely crenulate hyaline membrane.

Caudal rami (Figs. 5−7, 10) about 3 times longer than wide ($n = 9$). Outermost apical seta spine-like,

ornamented with row of spinules on both inner and outer margins and longitudinal row of setules on dorsal and ventral sides. Innermost apical seta 1.4 times longer than outermost apical seta and bearing stiff setules. Middle apical setae with stiff short setules proximally, setules becoming gradually longer and thinner towards tip. Dorsal seta as long as innermost apical seta.

Antennule 12-segmented. Setal armature as follows: 8, 4, 2, 6, 4, 2, 2, 3, 2, 2, 2, 7. Aesthetasc on segments 9, 11, and 12.

Antenna 5-segmented. Coxa very reduced and unarmed. Basis with 2 inner setae and outer seta (exopodite) reaching apex of terminal segment. Endopodite segments 1−3 spinulose on outer margin and with 1, 5, and 7 setae, respectively.

Labrum with 9 median denticles flanked by row of short spinules along free margin and 2 rows of long spinules on ventral surface.

Mandible (Fig. 11) reduced to coxa with gnathobase and short palp bearing 3 setae.

Maxillule consisting of powerful praecoxa (Fig. 12) and 2-segmented palp (Fig. 13). Praecoxal arthrite armed with 3 spines fused to segment and 1 articulated spine on distal margin and 7 elements on inner surface. Proximal segment (basis) of palp armed with 3 inner setae and 1 outer seta (exopodite). Distal segment (endopodite) reduced, armed with 3 setae.

Maxilla 4-segmented. Praecoxa fused to coxa on posterior surface. Setal formula: 2, 3, 3, 5.

Maxilliped 4-segmented. Setal formula: 3, 2, 2, 3.

Legs 1−4 armed as follows (Roman numerals representing spines; Arabic numerals indicating setae):

Coxa	Basis	Exopodite			Endopodite		
		1	2	3	1	2	3
Leg 1 0−1	1−I	I−1;	I−1;	III,2,3	0−1;	0−2;	I,I+1,3
Leg 2 0−1	1−0	I−1;	I−1;	III,I+1,4	0−1;	0−2;	I,II,3
Leg 3 0−1	1−0	I−1;	I−1;	III,I+1,4	0−1;	0−2;	I,II,3
Leg 4 0−1	1−0	I−1;	I−1;	II,I+1,4	0−1;		I,II,4*

* Endopodite segments 2 and 3 of leg 4 fused.

Figs. 8−11. Neocyclops (Protoneocyclops) ferrarii sp. n., ♀: 8, seminal receptacle, ventral (straight arrows indicating attachment areas of transverse cuticular thickening to integument of genital double somite; curved arrows indicating integumental pores); 9, seminal receptacle, lateral (meaning of straight arrow as in Fig. 8); 10, caudal rami, ventral; 11, mandible, inner. Scale bars 20 μm.
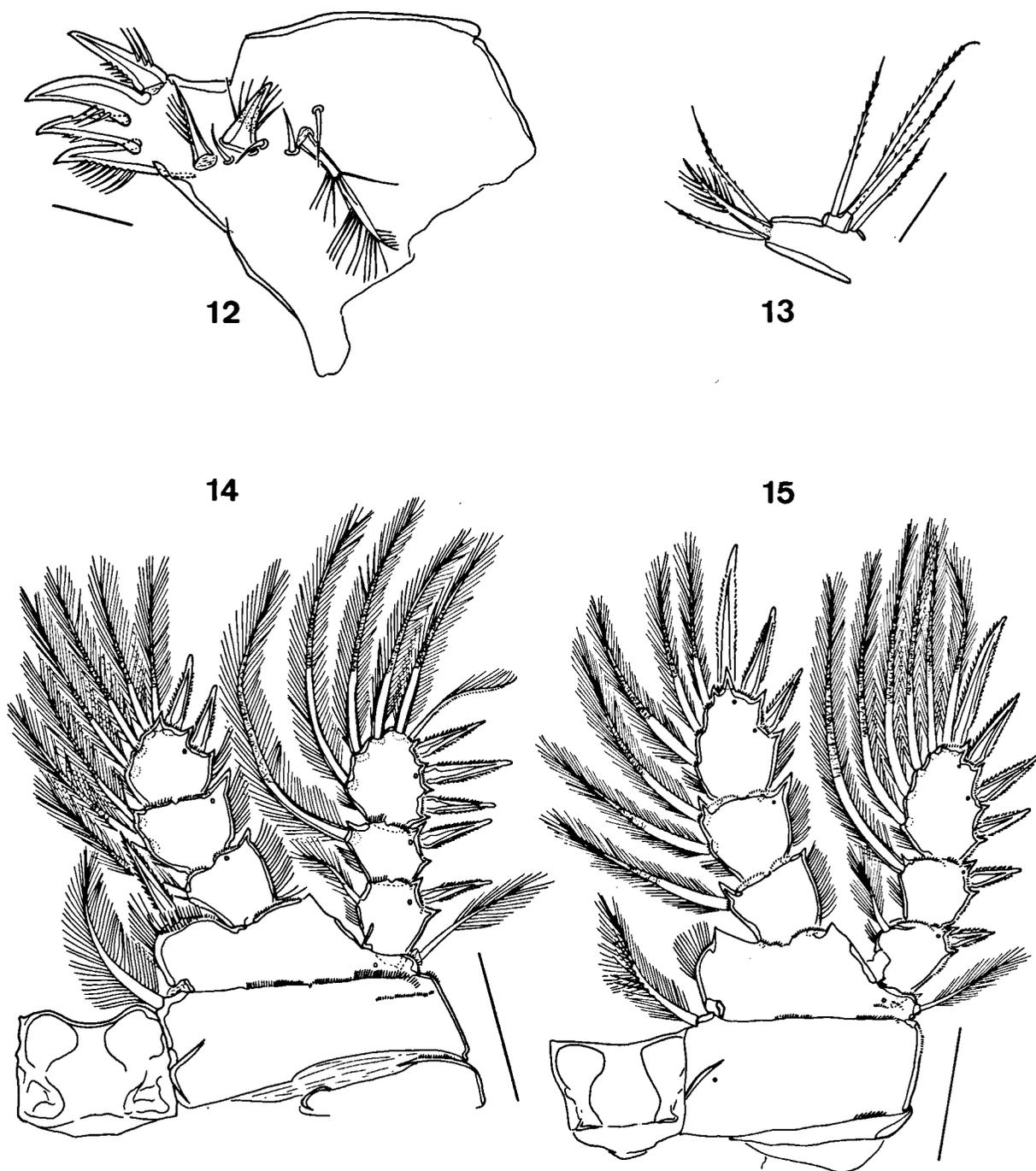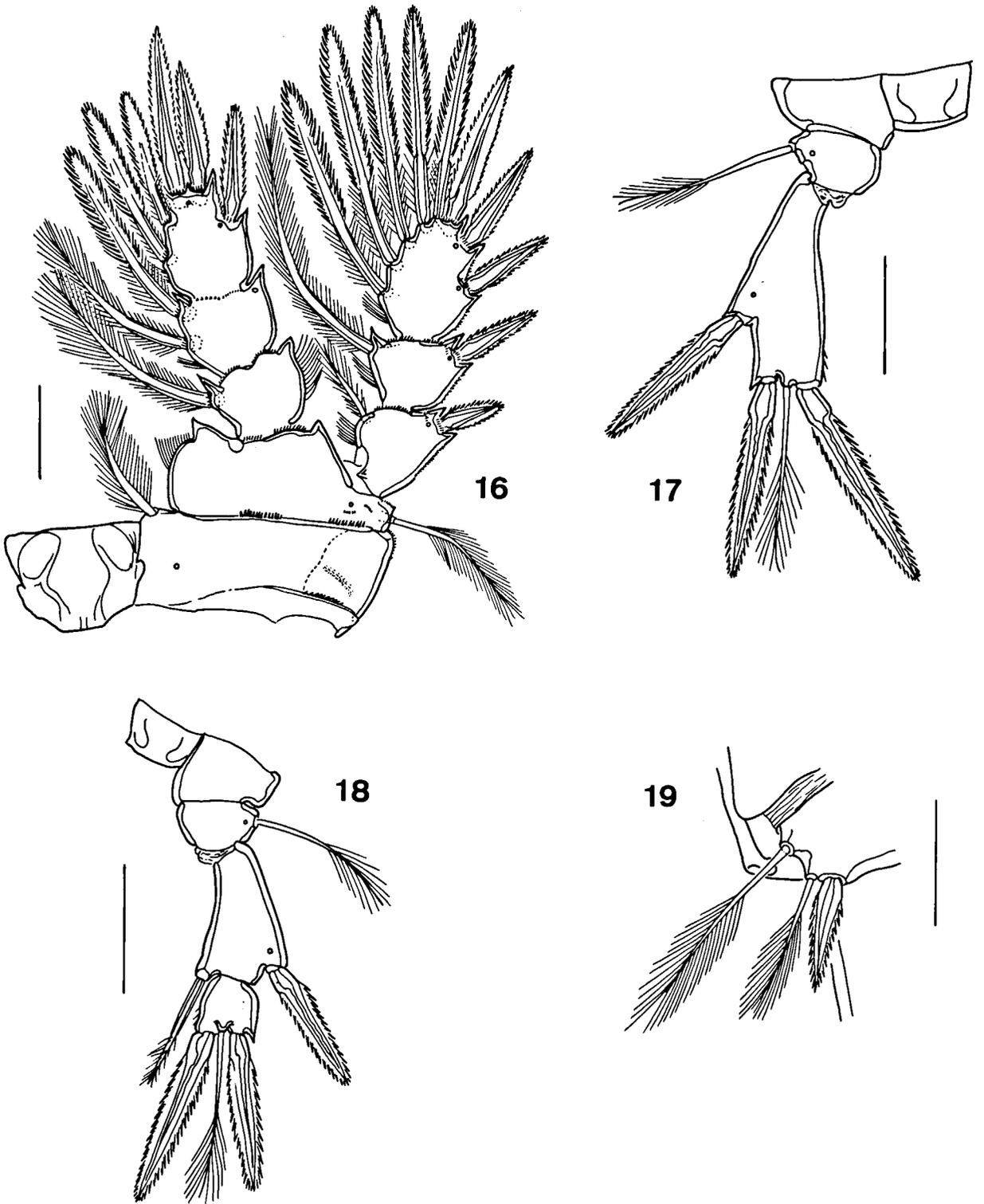
Figs. 12–15. Neocyclops (Protoneocyclops) ferrarii sp. n., ♀: 12, maxillular praecoxa, inner; 13, maxillular palp; 14, leg 1, anterior; 15, leg 3, anterior. Scale bars 20 μm (Figs. 12–13), 50 μm (Figs. 14–15).

Integumental pore pattern on anterior surface of legs 1, 3 (identical to leg 2) and 4 as in Figs. 14–16.

Leg 4 exopodite segment 3 (Fig. 16) with all inner setae modified, plumose proximally and with finely serrate hyaline membrane distally. Leg 4 endopodite segments 2 and 3 fused, row of tiny spinules on frontal surface indicating lost articulation between segments. Terminal endopodal segment of leg 4

Figs. 16–19. Neocyclops (Protoneocyclops) ferrarii sp. n.: 16, ♀ leg 4, anterior; 17, ♀ leg 5, anterior; 18, ♂ leg 5, anterior; 19, ♂ leg 6, anterior. Scale bars 30 µm.

bearing 3 setae resembling those of exopodite segment 3, none of them reaching tip of outer apical spine of segment.

Leg 5 (Fig. 17) with intercoxal sclerite and consisting of 3 segments. Coxa unarmed. Basis with integumental pore on anterior surface near implantation of outer seta. Exopodite twice longer than wide, armed with 3 spines and 1 seta. Inner apical spine little longer than segment (1.08−1.12 : 1). Outer apical spine 1.12 times longer than lateral spine, both shorter than exopodite. Integumental pore on anterior surface near indentation of proximal spine.

Male: Body length 520 to 580 μm ($n = 7$). Prosome : urosome ratio = 1.07−1.36 : 1. Urosome with 6 somites. Caudal rami 2.2 times longer than broad ($n = 5$). Antennule of 16 segments; armature as illustrated by Lotufo & Da Rocha (1993) for N. (N.) vicinus.

Leg 5 (Fig. 18) 4-segmented. Coxa and basis as in female. Exopodite segment 1 with outer spine and inner seta; segment 2 with one seta flanked by 2 spines.

Leg 6 (Fig. 19) consisting of inner spine and 2 setae; outer seta about 1.5 times length of middle seta.

The male is identical to the female in all other respects.

Etymology. − The species is named after Dr. Frank D. Ferrari, distinguished copepodologist at the National Museum of Natural History, Smithsonian Institution, Washington, and collector of the specimens.

Differential diagnosis. − The subgenus Protoneocyclops Petkovski, 1986 includes six species; N. (P.) mediterraneus (Kiefer, 1960); N. (P.) stocki Pesce, 1985; N. (P.) papuensis Fiers, 1986; N. (P.) wellsi Petkovski, 1986; N. (P.) herbsti Petkovski, 1986, and N. (P.) geltrudeae Pesce & Galassi, 1993. The latter three species share with N. (P.) ferrarii the presence of a plumose seta at the inner corner of the proximal exopodal segment of the male leg 5; the remaining species bear a variably shaped spine at that position.

Neocyclops (P.) ferrarii can be easily distinguished from N. (P.) geltrudeae as the latter species is peculiar in the armature of legs 4 and 5 in both sexes, as well as in the relative lengths of the inner apical and dorsal setae of the caudal rami. The separation of N. (P.) ferrarii from N. (P.) wellsi and N. (P.) herbsti is more difficult because of their more conservative morphology (Wells, 1967; Herbst, 1964). However, differences can be found in the length/width ratio of the caudal ramus, the relative lengths of inner and outer caudal apical setae, the seta representing the exopodite of the antenna, and the spines of leg 5, and finally in the length and structure of the two distalmost inner setae on the endopodite of leg 4.

Neocyclops improvisus from Cuba still has an undefined subgeneric position since the male of this species is unknown. The specimens from Belize cannot be ascribed to this species as they have an antennule of 12 segments, caudal rami 3 times longer than wide, innermost apical caudal seta longer than outermost one, and distalmost inner seta of terminal endopodal segment of leg 4 shorter than middle seta.

Remarks on the morphology of Neocyclops

Until now, all Neocyclops species have been described as having the first pediger fused with the cephalosome. In fact this somite is free although reduced and often hidden under the cephalic shield (Fig. 2). Perhaps this is the reason for the lack of any reference in previous papers. When concealed beneath the cephalic shield the limits of the somite look like fine lines hardly discernible in specimens still having internal tissues. But its existence as a separate somite is uncontestable when the soft tissues are removed. If partially or totally exposed, it is possible to observe the attachment areas of the muscles of legs 1 on the tergal plate (Fig. 3). Specimens of Neocyclops (Neocyclops) vicinus and N. (P.) medius in the author's collection showed the same condition warranting the supposition that the free pediger 1 is a consistent feature of the genus. Rocha & Iliffe (1994) considered this character state a plesiomorphy found only in Euryte and Troglocy-
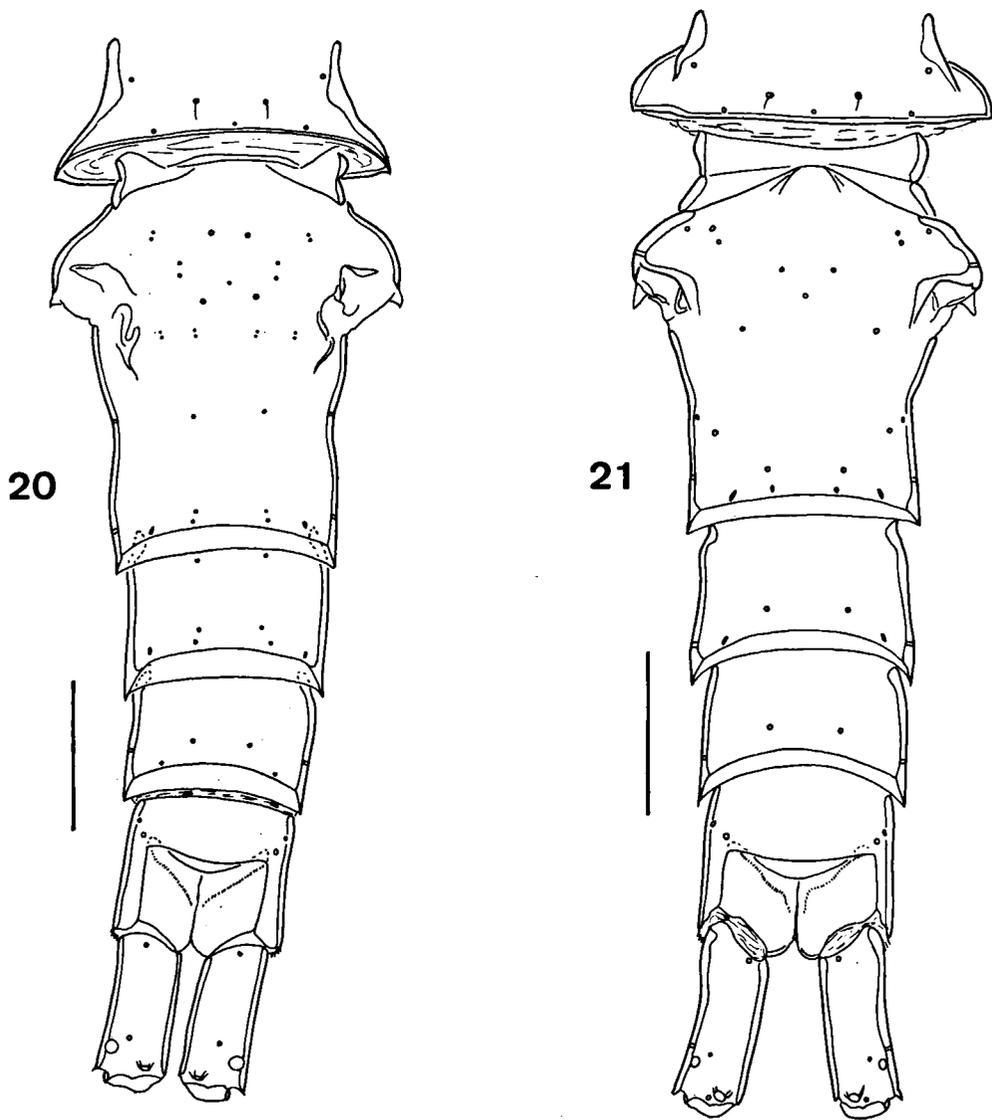
Fig. 20. Urosome of *Neocyclops* (*Neocyclops*) *salinarum* (Gurney, 1927) showing integumental pore pattern, dorsal.

Fig. 21. Urosome of *Neocyclops* (*Neocyclops*) *vicinus* (Herbst, 1955) showing integumental pore pattern, dorsal. Scale bars 50 μm.

clops, genera with the most ancestral character set within the Cyclopidae. Discovery of this feature in *Neocyclops* indicates its close relationship to these two marine genera.

Huys & Boxshall (1991) pointed out the existence of a pair of transverse ducts connected to the copulatory duct of the female seminal receptacle, a novel structure found only in cyclopids. These ducts seem to be absent in *N.* (*P.*) *ferrarii*, which has a transverse cuticular thickening partially fused

to the seminal receptacle and connected to the integument of the genital double somite by five attachment areas. Apparently this thickening supports the curved, tubular seminal receptacle. As the structure of the seminal receptacle is very conservative within the genus, it is here supposed that such thickening exists in all other species. If interspecific variations in shape and number of attachment areas of the thickening are known, it could be useful for separating *Neocyclops* species.
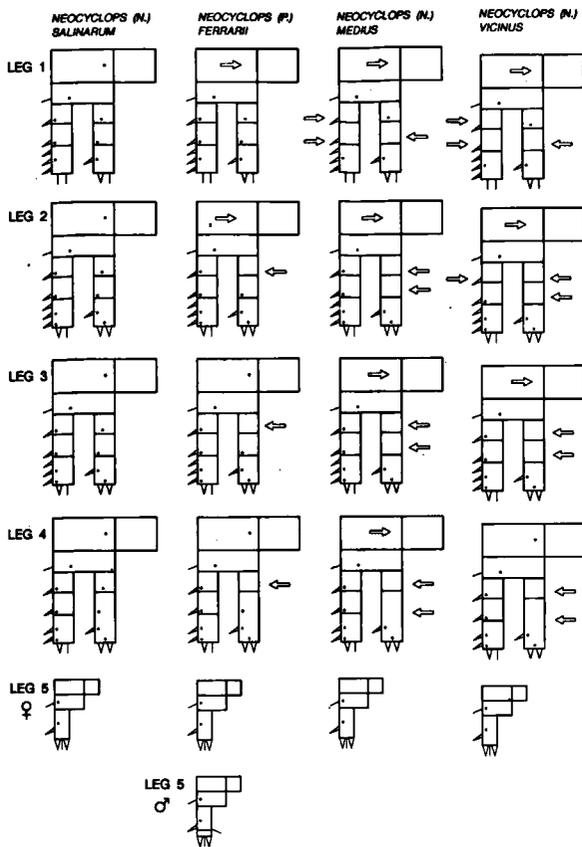
Fig. 22. Schematic comparison of integumental pore arrangement on the anterior surface of legs 1–5 of four species of *Neocyclops*. Pores present in *Neocyclops* (*Neocyclops*) *salinarum* but lacking in other species are indicated by arrows. The male leg 5 is illustrated only if differing from that of the female in number of segments and armature.

The great difficulty in studying the taxonomy of *Neocyclops* is the scarcity of diagnostic characters distinguishing species. Traditionally, distinctions between species have been based on the morphology of the caudal rami, segmentation of the antennule, armature of antenna and mandibular palp, and structure of legs 4 and 5, in some cases involving length ratios of the characters. The integumental pore pattern of the urosome could be helpful if known for a larger number of species than we know today. For instance, the patterns of the dorsal pores of the female urosome of *Neocyclops* (*N.*) *salinarum* (Gurney, 1927) and *N.* (*N.*) *vicinus* (Figs. 20–21) are provided here to be compared with that of *N.* (*P.*) *ferrarii* (Fig. 5). The pattern observed in *N.* (*N.*) *salinarum* differs significantly from those of the other two species, mainly in the genital double somite.

Cyclopid copepods have integumental pores on the anterior surface of legs 1 to 5. Originally there would have been a pore for each segment of the legs, except for the terminal segment of exopodite and endopodite of the legs 2 to 4 which bears two pores, arranged as in *N.* (*N.*) *salinarum* (Fig. 22). The coxal pore of legs 1 and 2 as well as the pore of the proximal segment of the endopodite of each of legs 2 to 4 are lacking in *N.* (*P.*) *ferrarii*. The number of pores is lower in *N.* (*N.*) *medius* and *N.* (*N.*) *vicinus* as illustrated in Fig. 22. The latter two species have similar pore numbers and position. These differences between four species suggest that the arrangement of the leg pores might also be useful in interpreting *Neocyclops* taxonomy.

Acknowledgements

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