

## New species of *Halicyclops* (Copepoda Cyclopidae) from the United States of America

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Received 23 April 1992; in revised form 1 September 1992; accepted 29 October 1992

**Key words:** Taxonomy, Crustacea, Copepoda, Cyclopoida, Atlantic Fauna, United States of America, estuaries, groundwater

### Abstract

Two new species of *Halicyclops*, *H. reidae* and *H. maculatus*, are described from the groundwater and marsh sediment of Wye Island, Maryland. *Halicyclops maculatus* is the first species of the genus to show sexual dimorphism in the males consisting of digitiform setae on the endopodite of swimming legs 1 and 2. *Halicyclops reidae* is the only American species of the genus having the inner distal seta of the leg 4 endopodite 3 plumose and the proximal seta spiniform.

A key for identification of the *Halicyclops* species from North America is provided.

M. S. Wilson (1958) provided the best historical review of knowledge of *Halicyclops* in North America, and described *H. fosteri*, the first valid species of the genus to be reported from the United States. Initially known from coastal brackish waters of Louisiana and Texas, *H. fosteri* had its range extended to the Chesapeake Bay by Burrell & Zwerner (1972) and to the Delaware Bay region by Lindsay (1974) and Aurand & Daiber (1979). Subsequently, four taxa were registered from the United States: *H. coulli* Herbst, 1977 from South Carolina and posteriorly recorded in Louisiana by Fleeger *et al.* (1983); *H. clarkei* Herbst, 1982 and *H. laminifer* Herbst, 1982 from Louisiana, and *H. hurlberti* Rocha, 1991 from San Diego, California. The finding of the two new species herein described increases to seven the number of *Halicyclops* species known from the USA.

### Material and methods

Specimens were collected from wells driven into the water table of a marsh and the adjacent riparian zone of Wye Island, Maryland on the eastern shore of the Chesapeake Bay (38° 54' N, 76° 08' W). Samples were collected by pumping water from wells which consisted of slotted PVC pipe (slot size *ca.* 250 µm) driven 1.5 and 0.5 m deep into saturated zone sediments for groundwater and marsh habitats respectively. The marsh and groundwater wells were located 20 and 30 m respectively inland from the Chesapeake Bay shoreline. Aquifer sediments consisted of poorly sorted sand (median grain size *ca.* 400 µm) with little silt or clay. Marsh sediments contained much more detrital material and had a higher silt content (median grain size *ca.* 200 µm). Salinity and pH of water samples collected from marsh wells

(8–12 ppt, pH 6) were always higher than in groundwater samples (0–10 ppt, pH 4). Oxygen values were always > 50% saturation in groundwater samples but rarely exceeded  $2 \text{ mg l}^{-1}$  in marsh water samples.

Whole specimens were examined in temporary lactic acid mounts. Fragments of cover glass were used to give support to the cover glass of the preparation. By moving the cover glass slowly and carefully by hand, the whole animal or a particular appendage was placed in different positions without damage, making possible observation of the morphological details without dissection. After examination, the specimens were returned and preserved in alcohol 70%.

The figures were prepared using a camera lucida on a Leitz Laborlux D phase-contrast microscope.

## Taxonomy

Family Cyclopidae G. O. Sars

Subfamily Halicyclopinae Kiefer

### *Halicyclops reidae* sp. n. (Figs 1–11)

**Material examined.** USA, Maryland, Wye Island: 3 females, 8 males collected from March to October, 1990, C. Hakenkamp col. Female holotype and 7 paratypes in the National Museum of Natural History, Smithsonian Institution, Washington D.C., USA (USNM 257017, and 257024, respectively). One female and 2 male paratypes in Museu de Zoologia, São Paulo, Brazil (MZUSP 11137).

**Female.** Body length range 515–670  $\mu\text{m}$  ( $N=3$ ). Prosome: urosome length 1.9–2.2: 1 ( $N=2$ ). Hyaline frills of all prosomites smooth (Fig. 1). Genital segment (Fig. 2) about 1.2 times wider than long, expanded into 2 blunt medio lateral protuberances. Hyaline frills of genital segment and 2 subsequent somites serrate; fourth urosomite (Fig. 2) having denticles of dorsal part of hyaline

frill longer than lateral denticles. Caudal ramus (Fig. 2) as long as wide or 1.2 times longer than wide; innermost apical seta very short (10  $\mu\text{m}$ ), difficult to distinguish from row of spinules along distal border of ramus; outermost apical seta 3 times longer than innermost apical seta; dorsal seta 2.4–2.9 times longer than ramus; inner middle apical seta (Fig. 3) bearing from 0 to 3 spinules on distal part of basal half, and with terminal half densely spinulose proximally and plumose distally; outer middle apical seta (Fig. 3) barbed, except on inner margin of basal half.

Antennule 6-segmented and armed as follows (Roman numerals indicating segments, Arabic numerals representing setae): I = 8, II = 12, III = 5 + spine, IV = 6 + aesthetasc, V = 2, VI = 10 + aesthetasc. Antennule segment 4 about twice longer than wide.

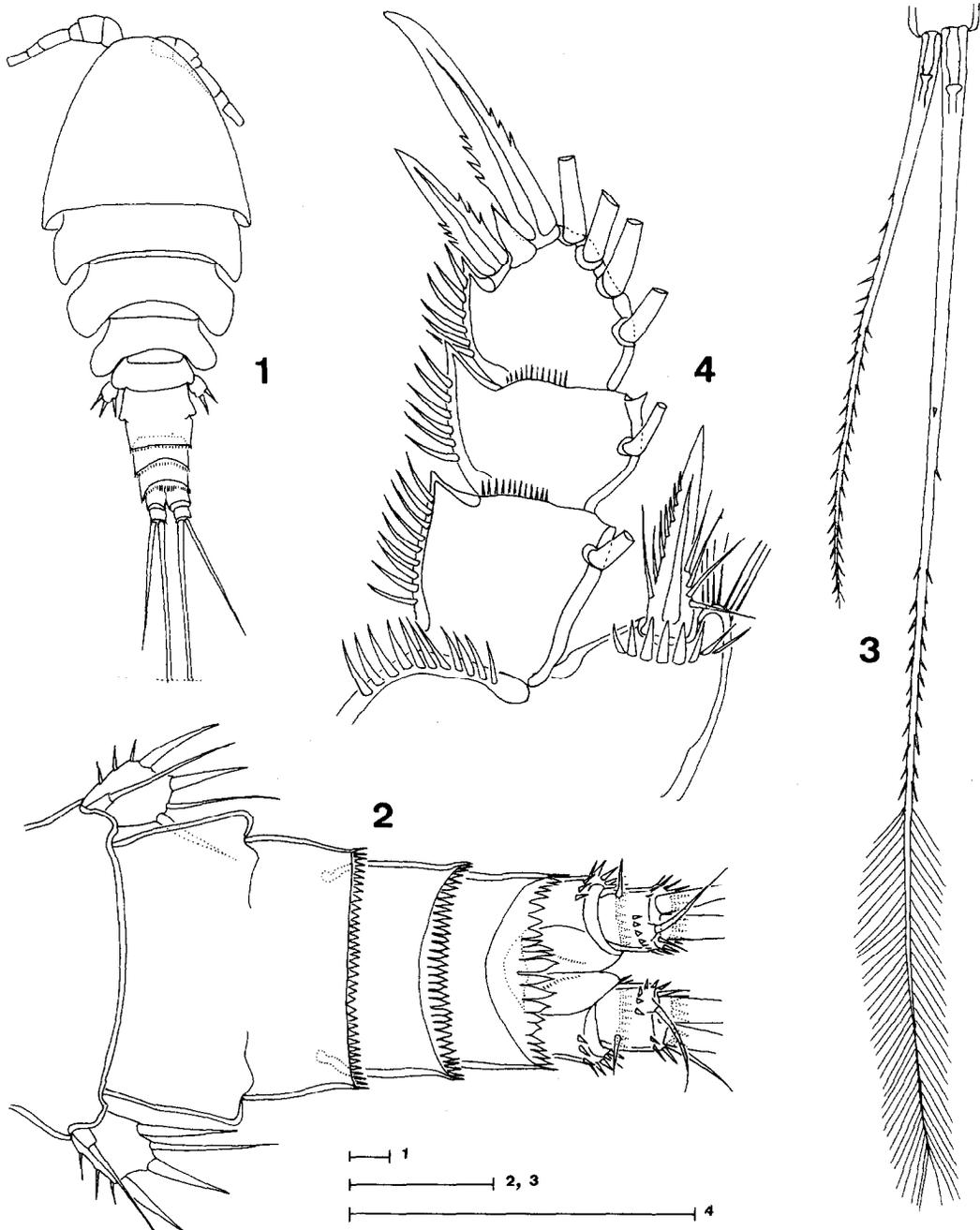
Antenna with distalmost segment 3 times longer than wide.

Mouthparts as those of *Halicyclops glaber* Rocha, 1983.

Swimming legs 1–4 armament as follows (Roman numerals indicating spines, Arabic numerals representing setae):

	Exopodite			Endopodite		
	1	2	3	1	2	3
Leg 1	I-1, I-1,	III-5		0-1, 0-1,	II-4	
Leg 2	I-1, I-1,	IV-5		0-1, 0-2,	III-3	
Leg 3	I-1, I-1,	IV-5		0-1, 0-2,	III-3	
Leg 4	I-1, I-1,	III-5		0-1, 0-2,	III-2	

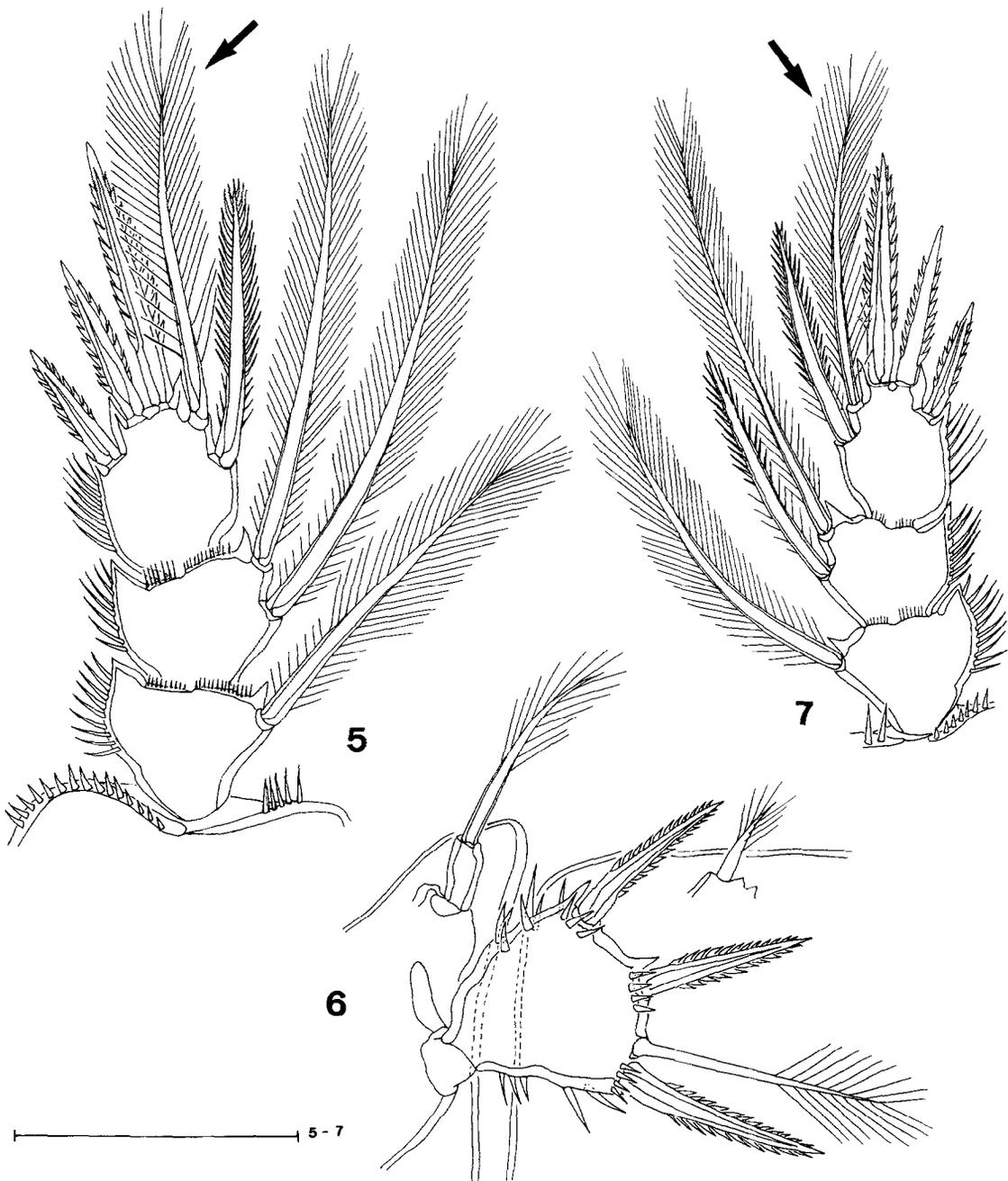
Spine inserted at inner corner of leg 1 basis (Fig. 4) reaching beyond level of insertion of seta of leg 1 endopodite 2. Spines of leg 1 exopodite similar in length to spines of exopodites of other swimming legs. Leg 2 and leg 3 similar, endopodite 3 of each with proximalmost inner seta modified as proximal seta of leg 4 endopodite 3. Leg 4 endopodite 2 (Fig. 5) with both setae plumose. Leg 4 endopodite 3 (Fig. 5) 1.07–1.16 times longer than wide; inner apical spine 1.4–1.8 times length of segment; outer apical spine as long



Figs 1-4. *Halicyclops reidae* sp. n. Female 1. habitus, dorsal; 2. urosome, dorsal; 3. middle apical setae of caudal rami, dorsal; 4. inner corner of basis and endopodite of leg 1, frontal surface (plumose setae cut). Scale bars = 50  $\mu$ m.

as segment; inner distal seta plumose and reaching beyond tip of inner apical spine; inner proximal seta spiniform as long as inner apical spine, serrate distally and plumose proximally.

Terminal segment of leg 5 (Fig. 6) triangular, as long as wide, with 3 spines and 1 seta; outer and apical spines similar in length and little shorter than segment; inner spine 1.1 times longer

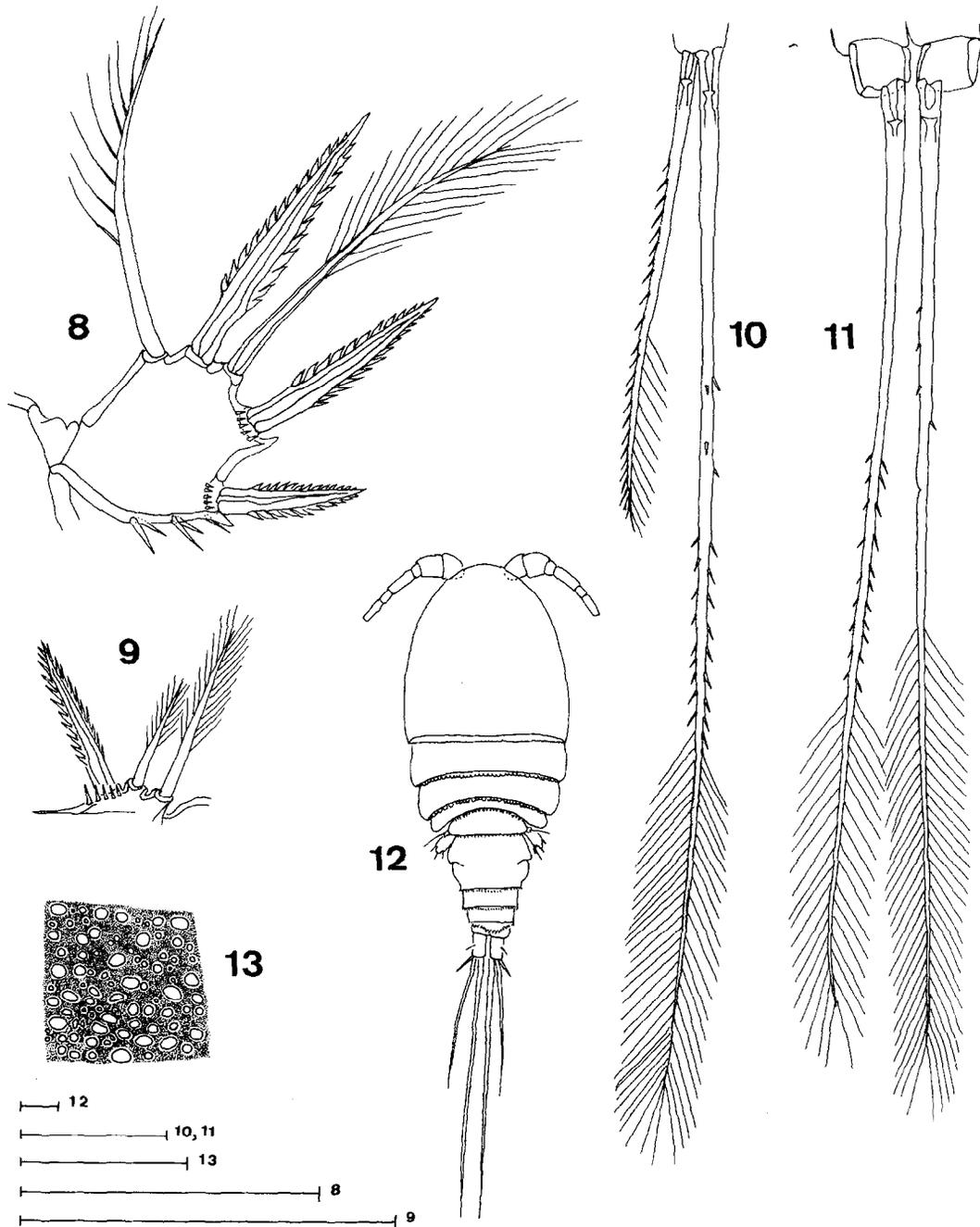


Figs 5–7. *Halicyclops reidae* sp. n. Female 5. leg 4 endopodite, frontal surface; 6. leg 5 and leg 6. Male 7. leg 4 endopodite, frontal surface. Scale bar = 50  $\mu$ m.

than segment and 1.2 times longer than other spines.

**Male.** Body length range 455–550  $\mu$ m ( $N = 5$ ).  
 Prosome: urosome = 1.5–1.8:1. Leg 4 endopodite

(Fig. 7) differing from that of female only in having proximal seta of second segment modified like proximal seta of third segment. Terminal segment of leg 5 (Fig. 8) as long as or little longer than wide, and bearing 3 spines and 2 setae similar in



Figs 8–13. *Halicyclops reidae* sp. n. Male 8. terminal segment of leg 5; 9. leg 6; 10. middle apical setae of caudal rami, showing normal armament; 11. middle apical setae of caudal rami of another specimen with abnormal armament. *Halicyclops maculatus* sp. n. Female 12. habitus, dorsal; 13. portion of tergal surface of cephalosome showing different size of refractile points. Scale bars = 50  $\mu$ m.

length; inner spine about 1.4 times longer than segment and apical spine, and twice longer than outer marginal spine. Leg 6 (Fig. 9) represented

by inner spine and 2 setae, outer seta about 1.5 times longer than middle seta.

Outer middle apical seta of caudal ramus

(Fig. 10) plumose on inner margin of distal half. One male with both inner middle apical setae abnormally ornamented (Fig. 11). Antenna, mouthparts and legs 1–3 identical to those of female.

*Etymology.* The species is named after Dr Janet W. Reid, Smithsonian Institution, Washington, D.C.

*Habitat.* The majority of the specimens were collected from the marsh of Wye Island, Maryland. Only one female was collected in a groundwater well.

*Differential diagnosis.* Within the genus, *H. dedeckeri* Brownell, 1983, *H. higoensis* Ito, 1957, and now *H. reidae* sp. n. are the only species possessing the distal inner seta of the leg 4 endopodite 3 plumose and the proximal inner seta of that article spiniform. In addition, *H. reidae* shares with *H. dedeckeri* short caudal rami, and the frill of the urosomite 4 with mediad dorsal denticules longer than the lateral denticules. However, *H. dedeckeri* has a chitinous, sharp spine curved backwards on each side of the genital segment; *H. reidae* has the genital segment expanded into blunt protuberances directed laterally. On the other hand, *H. reidae* differs from *H. higoensis* in having a relatively shorter dorsal seta on the caudal ramus, longer spines on the leg 4 endopodite 3 as well as on the terminal segment of the leg 5, and the posterior borders of all urosomites with hyaline frills denticulate.

*Halicyclops maculatus* sp. n.  
(Figs 12–29)

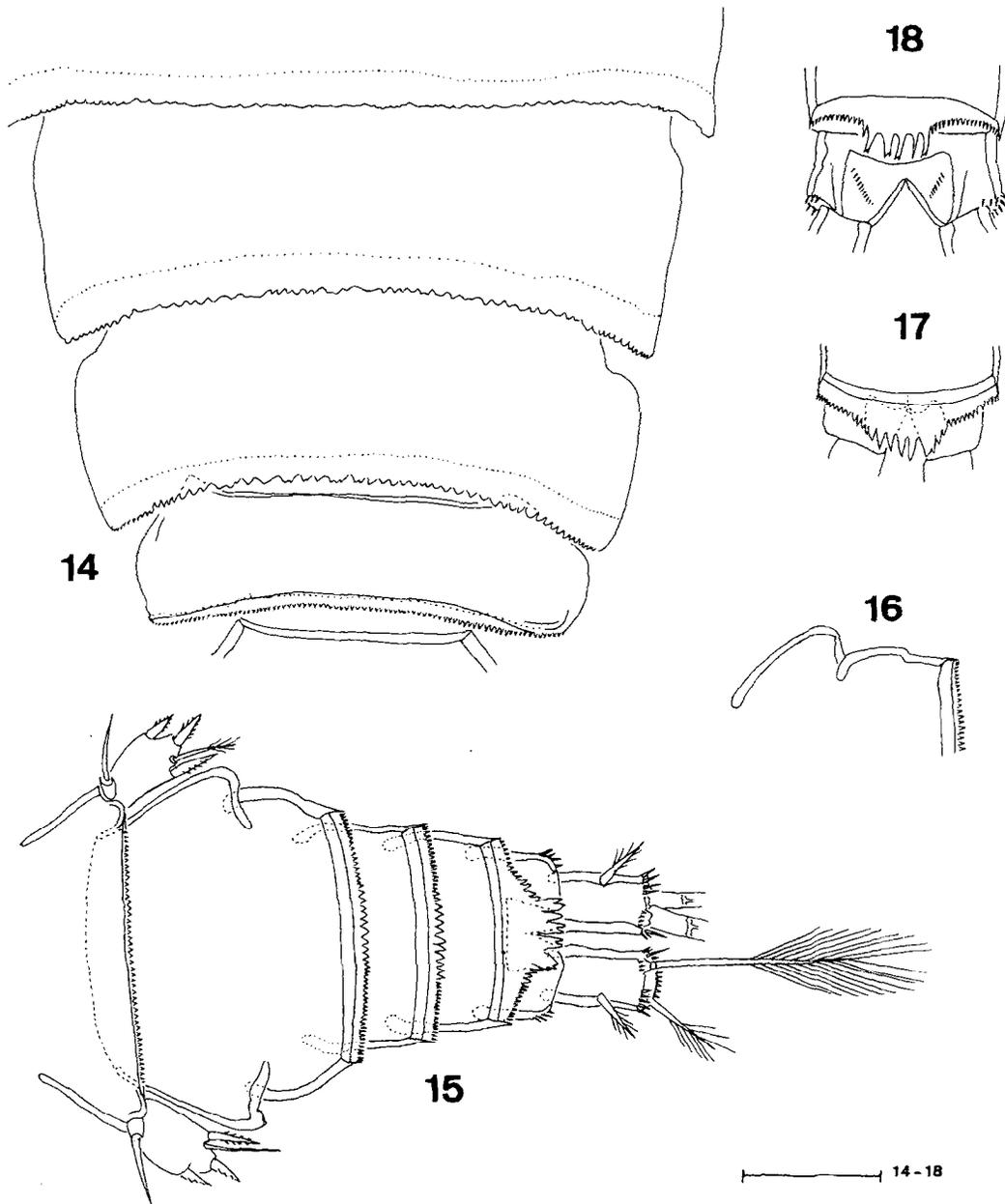
*Material examined.* USA, Maryland, Wye Island: 4 females, 1 male collected from September to October, 1990, C. Hakenkamp col. Female holotype and 3 paratypes in the National Museum of Natural History, Smithsonian Institution, Washington D.C., USA (USNM 257013, and 257019, respectively).

One female paratype in Museu de Zoologia, São Paulo, Brazil (MZUSP 11138).

*Female.* Body length range 580–620  $\mu\text{m}$  ( $N = 3$ ). Prosome:urosoma = 1.38–1.63:1. Tergal plates of prosoma and dorsal surface of urosoma with refractile points (Fig. 13). Hyaline frills of all prosomites irregularly serrate (Figs 12 and 14). Genital segment (Fig. 15) about 1.4 times wider than long and protruded in alliform process on each side at midlength; posterior half slightly inflated and with small lateral protuberance (Fig. 16). Hyaline frills of genital segment and urosomite 3 (Fig. 15) serrate all around their extensions; mediad dorsal denticules larger than lateral and ventral ones. Frill of urosomite 4 (Fig. 15) enlarged dorsally in false anal operculum; mediad denticules of this false operculum larger than lateral ones and more or less coalesced with each other forming opercula of different aspects (Figs 15, 17, 18). Caudal rami (Fig. 15) 1.7–1.8 times longer than wide; outer apical seta little shorter than ramus and 3.3 times longer than inner apical seta; dorsal seta plumose and about 2.3 times longer than outer apical seta; outer middle apical seta (Fig. 19) spinulose on outer margin and plumose on inner margin of distal half; inner middle apical seta (Fig. 19) with proximal half smooth; distal half with group of 10 to 13 proximal setules thicker and shorter than slender setules of more distal part of seta.

Antennule with same armament as *Halicyclops reidae*; fourth segment 2.3–2.5 times longer than wide. Antenna segment 3 (Fig. 20) 3.5–4.0 times longer than wide and bearing 8 setae on inner margin.

Armament of legs 1–4 as in *H. reidae*. Basis of leg 1 (Fig. 21) with inner spine shorter than endopodite 1. One specimen with proximal spine of endopodite 3 of left leg 3 replaced by row of 3 strong spiniform projections. Endopodite 3 of legs 2–3 with proximalmost inner seta modified as proximal seta of leg 4 endopodite 3. Leg 4 endopodite 2 (Fig. 22) with both setae plumose. Leg 4 endopodite 3 (Fig. 22) 1.25–1.3 times longer than wide; inner apical spine 1.35–1.4 times length of segment and outer apical spine; both inner setae spiniform, similar in length to each other, and smooth proximally and spinulose distally; distal seta reaching beyond inner apical



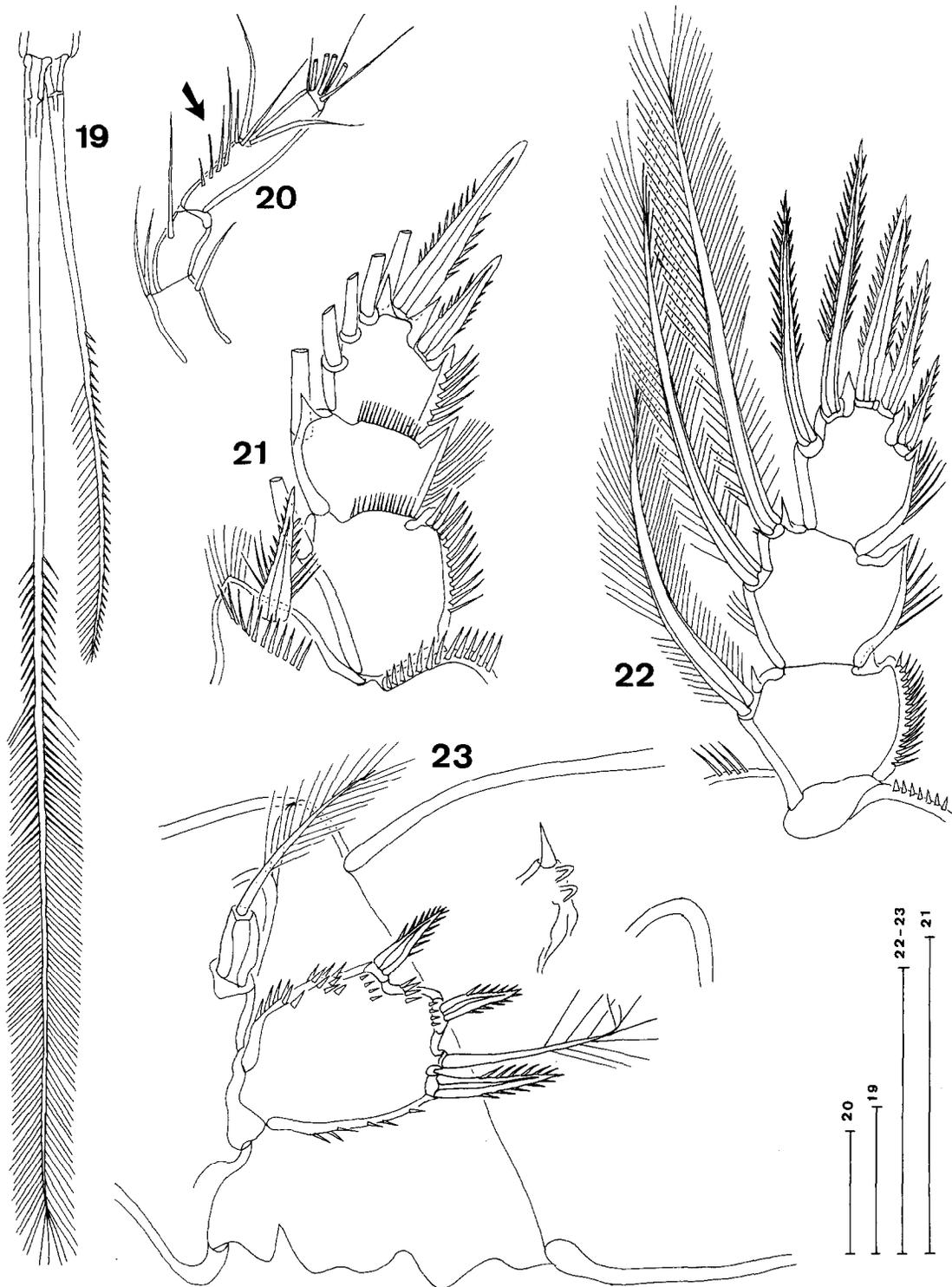
Figs 14-18. *Halicyclops maculatus* sp. n. Female 14. posterior part of cephalosome and prosomites 2-4 with hyaline frills irregularly serrate (dotted line indicates posterior limit of area of refractile points in each somite, dorsal); 15 urosome, dorsal; 17-18. different anal opercula, dorsal; 16. genital segment partially represented, showing both lateral protuberances, ventro-lateral. Scale bar = 50  $\mu$ m.

spine and 1.8 times length of segment; proximal seta reaching tip of inner apical spine.

Terminal segment of leg 5 (Fig. 23) rectangular, 1.4 times longer than broad, and bearing 3 spines, all shorter than segment, and 1 seta; inner spine

1.6 times longer than apical spine and 1.4 times length of outer spine.

Leg 6 (Fig. 23) represented by spiniform seta and 2 spines.

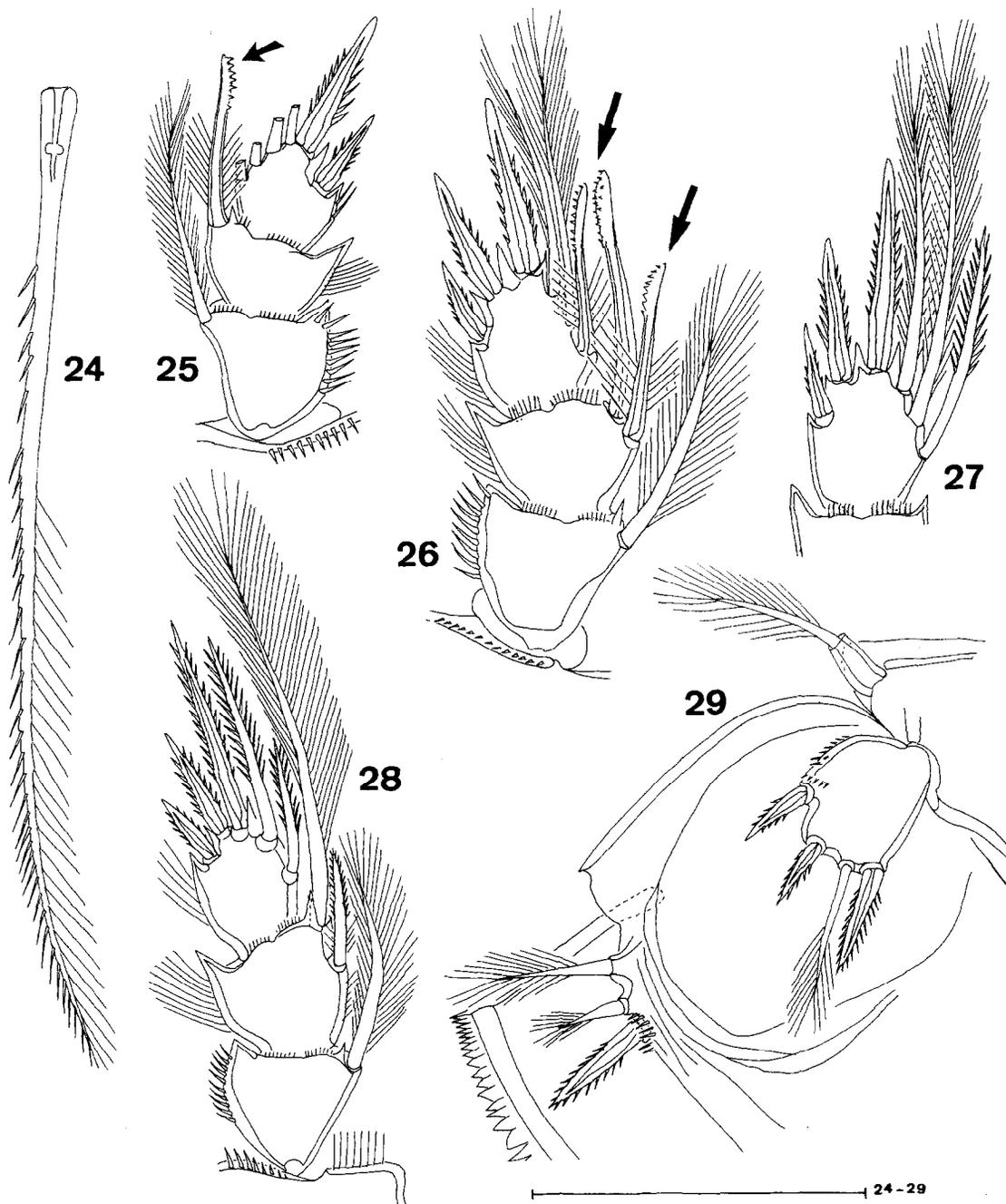


Figs 19–23. *Halicyclops maculatus* sp. n. Female 19. middle apical setae of the caudal rami; 20. antenna (apical setae cut); 21. leg 1, inner distal corner of basis and endopodite, frontal surface (plumose setae cut); 22. leg 4 endopodite, posterior surface; 23. urosomite 1 and anterior part of genital segment, bearing leg 5 and leg 6, lateral. Scale bars = 50  $\mu$ m.

*Male*. Body length 460  $\mu\text{m}$ . Posterior borders of prosomites and dorsal surface of body ornamented as in female. Outer middle apical seta

(Fig. 24) spinulose on outer margin, and densely plumose on inner margin of distal 2/3 of seta.

Leg 1 endopodite 2 (Fig. 25) with digitiform



Figs 24–29. *Halicyclops maculatus* sp. n. Male 24. outer middle apical seta of caudal rami, dorsal; 25. Leg 1 endopodite, frontal surface; 26. Leg 2 endopodite, frontal surface; 27. Leg 3 endopodite 3, frontal surface; 28. Leg 4 endopodite, frontal surface; 29. part of urosome showing leg 5 and leg 6, ventro-lateral. Scale bar = 50  $\mu\text{m}$ .

seta plumose proximally and serrate distally on outer side. Leg 2 (Fig. 26) having both setae of endopodite 2 and proximal seta of endopodite 3 modified as seta of leg 1 endopodite 2. Leg 3 endopodite 3 (Fig. 27) armed as in female. Leg 4 endopodite 3 (Fig. 28) with inner apical spine twice longer than outer apical spine and segment; both its inner setae spiniform and shorter than inner apical spine; distal seta 1.5 times longer than proximal one. Leg 4 endopodite 2 (Fig. 28) having proximal seta spiniform, plumose basally and serrate terminally.

Terminal segment of leg 5 (Fig. 29) bearing 3 spines and 1 seta as in female. Leg 6 (Fig. 29) represented by inner spine as long as outer seta and twice longer than median seta.

*Etymology.* The specific name (from the Latin *maculatus*, spotted) refers to the refractile points on the dorsal surface of the body.

*Habitat.* *H. maculatus* occurred exclusively in a marsh of Wye Island, Maryland. On two occasions (September and October, 1990) it occurred together with *H. reidae*.

*Differential diagnosis.* *H. maculatus* is readily distinguishable from all other species of the genus by the spots (refractile points) present on the dorsal surface of the body, by the setation of the inner margin of the antenna in both sexes, and by the remarkable dimorphism in the endopodites of legs 1 and 2 in the male.

Although *H. denticulatus* was not completely described by Kiefer (1960) and Wells (1967), it is the *Halicyclops* species which most resembles *H. maculatus*. Both species share a similar leg 5, the serrate distal border of the prosomites, an anal operculum formed from coalesced hyaline denticules on the dorsomedial region of the distal edge of urosomite 4, and absence of sexual dimorphism in leg 5. Beside those diagnostic characters previously indicated for *H. maculatus*, these two species differ in the shape of the genital segment and the length of the caudal rami.

*H. maculatus* is the sixth known *Halicyclops* species in which a false anal operculum is formed

from coalesced hyaline denticules. This feature was previously observed only in *H. denticulatus* Kiefer, 1960; *H. gauldi* Plesa, 1961; *H. stocki* Herbst, 1962; *H. reunionensis* Bozic, 1964; *H. laminifer* Herbst, 1982; and *H. paradenticulatus* Rocha, 1984.

Named species in which the animals bear denticulate hyaline frills on the posterior border of some or all of the prosomites now number four: *H. denticulatus* Kiefer, 1960; *H. stocki* Herbst, 1962; *H. paradenticulatus* Rocha, 1984; and the new species. In *H. denticulatus* the denticules are lacking on the cephalosome border, while in *H. stocki* denticules are present on the border of the last prosomite and first urosomite; in the latter two species all urosomites have those borders serrate.

#### Key to *Halicyclops* species in North America

As the known *Halicyclops* species in the United States now number 7, it is reasonable to present a key to aid in their identification. Only the species considered valid are included. The European species *H. magniceps* (Lilljeborg), reported from the Yucatan Peninsula by C. B. Wilson (1936), and from Woods Hole by C. B. Wilson (1932) and Deevey (1948), is not included because these authors' identifications are questionable. Rocha (1991) has demonstrated that the records of *H. aequoreus* (Fischer, 1860) from Lake Pontchartrain, Louisiana, which appeared in Marsh (1910, 1913) are actually of *H. fosteri*. Another questionable record is that of Comita (1951), who identified some specimens from a brackish lagoon near Acapulco as *H. aequoreus propinquus*. According to M. S. Wilson (1958), Comita's identification would be apparently based on Gurney's (1933) misapplication of the name *propinquus* given by Sars (1905) to specimens from the Chatham Islands, Pacific Ocean.

The key is based mainly on the morphology of the females. References to the males are included in species which have sexually dimorphic features which may aid in their identification. The step leading to the identification of a taxon has more

than one character in order to make identification more consistent and reliable.

1. Hyaline frills of prosomites irregularly serrate; dorsal surface of body with refractile points; caudal rami 1.7–1.8 longer than broad; male with seta on leg 1 endopodite 2, both setae of leg 2 endopodite 2, and proximal seta of leg 2 endopodite 3 digitiform and distally denticulate ..... *H. maculatus* sp. n.
  - Hyaline frills of prosomites smooth; dorsal surface of body without refractile points in tergal plates; caudal rami about 1.0–1.5 times longer than broad ..... 2
2. Legs 1–4 exopodite 3 with spine formula 3,4,4,2; false anal operculum not present; inner setae of leg 4 endopodite 3 lacking in female; male with 2 spiniform setae on leg 4 endopodite 3, these setae not reaching tip of inner apical spine ... *H. fosteri* M. S. Wilson, 1958
  - Legs 1–4 exopodite 3 with spine formula 3,4,3,3; false anal operculum present; inner setae of leg 4 endopodite 3 spiniform and shorter than apical spine; antennule segment 4 as long as broad; male unknown ..... *H. laminifer* Herbst, 1982
  - Legs 1–4 exopodite 3 with spine formula 3,4,4,3 ..... 3
3. Genital segment wider than long and expanded in 2 blunt lateral protuberances; leg 4 endopodite 3 with inner distal seta plumose and proximal seta spiniform and serrate ..... *H. reidae* sp. n.
  - Genital segment as long as or longer than wide and expanded only in anterior half .. ..... 4
4. Terminal segment of leg 5 with 3 stout spines, all spines shorter than segment; leg 4 endopodite 3 with inner apical spine about 1.1 times longer than segment; inner distal seta of leg 4 endopodite 3 as stout as apical spines, serrate and straight ..... *H. clarkei* Herbst, 1982
  - Terminal segment of leg 5 with 3 slender

spines, all spines as long as or longer than segment ..... 5

5. Leg 4 endopodite 3 with inner setae similar to each other, both setae reaching beyond tip of inner apical spine ..... *H. coulli* Herbst, 1977
  - Leg 4 endopodite 3 with inner distal seta stouter than apical spines and inner proximal seta, coarsely serrate distally, and slightly curved inwards; in female, only this seta reaching beyond tip of inner apical spine; in male, this seta straight, and not reaching tip of inner apical spin ..... *H. hurlberti* Rocha, 1991

### Acknowledgements

We are grateful to Dr J. W. Reid who kindly reviewed the manuscript. This research was funded by the Chesapeake Bay Fund, Maryland Agricultural Experiment Station, and National Science Foundation grants R11 – 8620422 and BSR 9006002.

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