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*PARAUGAPTILUS* (COPEPODA: CALANOIDA): TWO SPECIES, ONE NEW, FROM THE SARGASSO SEA<sup>1</sup>

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Four species of *Paraugaptilus* have been described: *P. buchani* Wolfenden 1904 from 59°–60° N in the eastern Atlantic, *P. similis* Scott 1909 from the Malay Archipelago, *P. meridionalis* Wolfenden 1911 from west of the Cape Verde Islands in the Atlantic, and *P. mozambicus* Gaudy 1965 from the Indian Ocean off Madagascar. Wolfenden (1904, 1911) described *P. buchani* from a single female specimen and *P. meridionalis* from two females; these species differ primarily in the relative lengths of the cephalothorax and urosome and caudal rami and in the size and degree of protrusion of the female genital segment. Scott (1909) described both male and female *P. similis* from 26 specimens, including 14 females and 12 males. Gaudy (1965) had 14 females, 5 males and 3 copepodites of *P. mozambicus*. Sars (1924, 1925) identified and described as *P. buchani* male and female specimens collected near the Azores and west of the Canary Islands; however, his description differs from Wolfenden's, and it is unlikely that he had this species.

There have been no further records of *P. similis* and *P. meridionalis*, but undocumented reports of the occurrence of *P. buchani* have been published by Sars (1907), Farran (1908), Lysholm, Nordgaard and Wiborg (1945), Fraser (1961), Vervoort (1965), Calef and Grice (1967), and Roe (1972). Esterly (1911) recorded and figured female specimens from off the

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California coast. Wilson (1950, Figs. 382, 383) listed female and male *P. buchani* from stations in the Philippines and off the Alaska Peninsula; he figured only the fifth legs of the two females, and both differed from *P. buchani*, one closely resembling those of female *P. similis*. Tanaka (1964) described and figured an immature female he referred to *P. buchani*, but the structure of the first maxilla differs from that of *P. buchani*. Species of this genus have therefore been only rarely recorded.

Zooplankton samples were collected monthly, between July 1968 and September 1970, over four depth levels between the surface and 2,000 m at Station "S", 32°10'N, 64°30'W, in 3,200 m of water, in the Sargasso Sea 15 miles southeast of Bermuda (Deevey and Brooks, 1971). Continued sampling at this station yielded 39 specimens of *Paraugaptilus*, including 19 *P. buchani* Wolfenden, 19 of a new species, and a single male with different fifth legs, possibly malformed *P. buchani*. The new species is very close to *P. mozambicus* Gaudy in the shape of the female genital segment, but differs in other respects. Specimens of *Paraugaptilus* were caught usually in spring and summer only within the upper 1,000 m, and predominantly between 500 and 1,000 m.

#### Genus *Paraugaptilus* Wolfenden 1904

Head narrowed anteriorly, separated or weakly fused with 1st thoracic segment. Two long slender divergent rostral filaments. Fourth and 5th thoracic segments fused, posterior margin slightly indented laterally, with a short dorsal tooth or curved spine on each side. Urosome 4 segmented in female, 5 segmented in male. First antenna of 20–21 segments; male left first antenna geniculate, of 18–20 segments. Endopodite of second antenna much longer than exopodite. Mouth-parts similar to those of *Arietellus*. Mandibular palp uniramous. Maxilla 1 with greatly reduced inner lobe. Long distal bristles of maxilla 2 and maxilliped furnished with augaptiloid cups as in *Augaptilus*. Leg 1 with long outer edge spines. Legs 1–4 with 3-segmented rami, although endopod of female leg 1 may not be completely segmented. Female 5th legs consisting of a foliaceous plate not separated on midline, with lateral and distal setae. Male 5th legs 3 jointed, with rudimentary endopodites, last segment of left leg with pincerlike spines.

#### KEY TO FEMALES OF *PARAUGAPTILUS*

1. Urosome relatively short, not more than 30% of cephalothorax length ..... 2

- Urosome at least 33% of cephalothorax length ..... 3
2. First antenna short, not as long as cephalothorax, genital segment with asymmetrically placed ventral prolongation, caudal rami twice as long as wide ..... *P. mozambicus* Gaudy 1965
- First antenna as long as or longer than cephalothorax, genital segment rounded ventrally, caudal rami less than twice as long as wide ..... *P. buchani* Wolfenden 1904
3. First antenna extending to urosome, dorsal and lateral thoracic segments covered with hairs ..... *P. similis* Scott 1909
- First antenna approximately length of cephalothorax, thoracic segments without hairs, caudal rami at least twice as long as wide ... 4
4. Genital segment with asymmetrical ventral prolongation, dorsal urosome hairy ..... *P. bermudensis* new species
- Genital segment only slightly swollen ventrally, no hairs on body ..... *P. meridionalis* Wolfenden 1911 (also *P. buchani*.—Sars 1925)

KEY TO MALES OF *PARAUGAPTILUS*

1. Urosome 30% or less of cephalothorax length ..... 2
- Urosome 33% or more of cephalothorax length ..... 3
2. Right 1st antenna less than cephalothorax length .....  
..... *P. mozambicus* Gaudy 1965
- Right 1st antenna at least as long as cephalothorax .....  
..... *P. buchani* Wolfenden 1904
3. Dorsal thorax hairy, urosome without hairs ..... *P. similis* Scott 1909
- Dorsal thorax without hairs, dorsal urosome hairy .....  
..... *P. bermudensis* new species

***Paraugaptilus bermudensis*, new species**

*Material*: Male 2.75 mm, VII/30/68; Female 2.90 mm, IX/12/68; Female 2.90 mm, Male 2.70 mm, XII/19/68; Female 3.00 mm, 2 males 2.80 mm, VI/25/69; Female 2.75 mm, immature female 2.50 mm, VII/22/69; Female 2.90 mm, VIII/11/69; Female 2.75 mm, V/20/70; 2 Females 2.80 mm, 2.90 mm, VII/11/70. 0–500 m night haul. Female 3.00 mm, 500–1,000 m day haul; Female 2.90 mm, immature female 1.95 mm, VIII/21/70; Immature female 2.00 mm, male 2.70 mm, IX/15/70; Male 2.75 mm, IX/16/70.

*Locality*: Station "S", 32°10'N, 64°30'W. All specimens caught between 500 and 1,000 m, except 2 females taken in a 0–500 m night tow.

Female holotype, 2.80 mm long, on 2 slides, collected in a 0–500 m night haul, VII/11/70, and male allotype, 2.70 mm, on 2 slides, collected XII/19/68, 500–1,000 m depths, will be deposited in the National Museum of Natural History. Paratypes are deposited in Florida State Museum, University of Florida.

*Description*: Female (Fig. 1a-h; Fig. 3a, e-g, i, j): 2.75–3.00 mm total length. Head narrowed anteriorly, around ½ cephalothorax length, separated but weakly fused with 1st thoracic segment. Cephalothorax

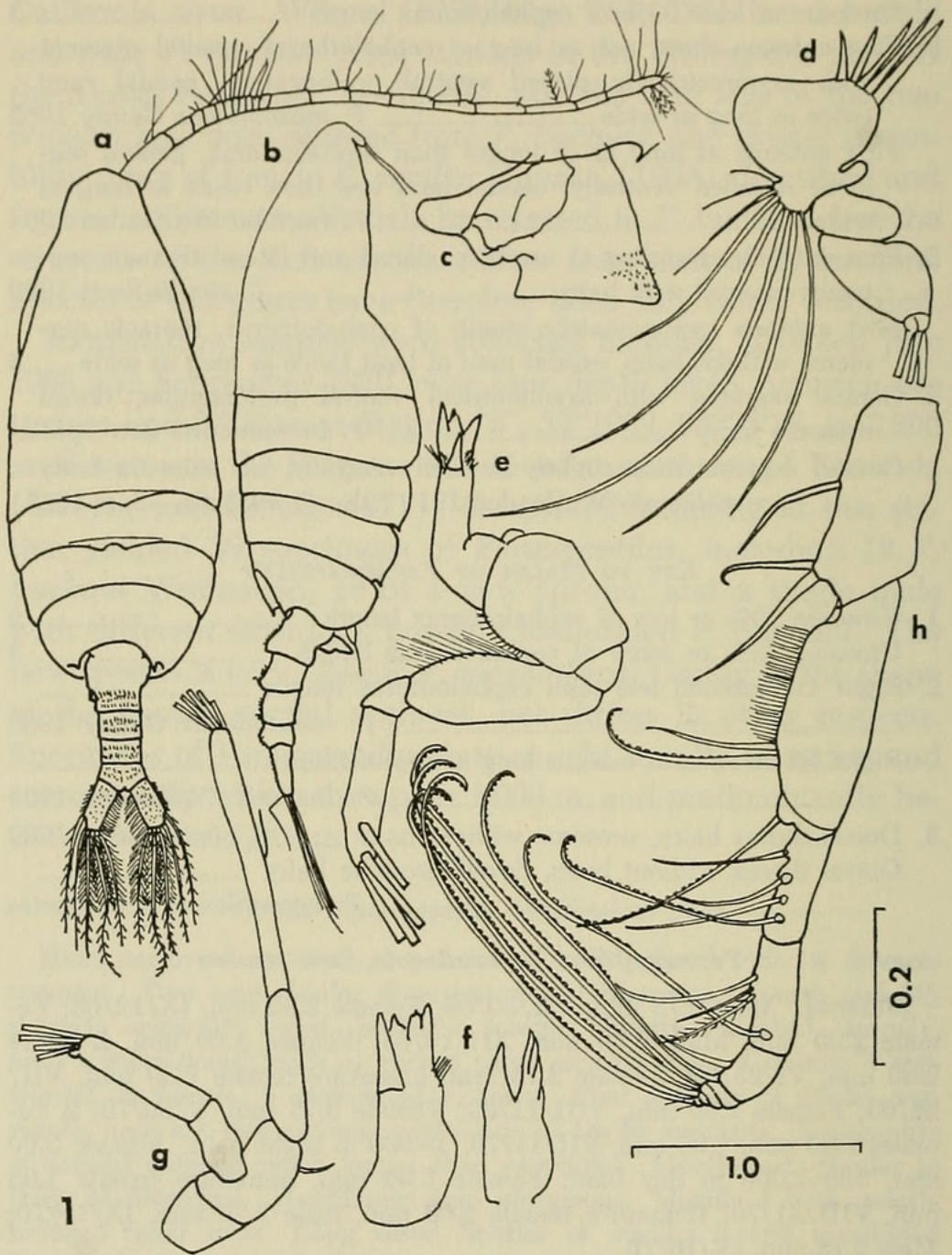


FIG. 1. *Paraugaptilus bermudensis*, new species, Female. a, and b, Dorsal and lateral views of female; c, Lateral view of genital segment from left side; d, Maxilla 1; e, Mandible; f, Other views of mandible blade; g, Second antenna; h, Maxilliped. Scale at bottom right for a and b, on right margin for c-h. Scales in mm.

76–78% of total length, 4th and 5th thoracic segments fused, the posterior dorsolateral edge produced to a sharp hooked spine, clearly visible in lateral view (Fig. 1b, c). Urosome 33–34% of cephalothorax length; covered dorsally, except for the anterior genital segment, with hairs or spinules. Caudal rami twice as long as wide, with hairs on inner and outer margins; 5 caudal setae, 2nd inner longer than others, the 3 inner setae jointed near base and strikingly and darkly plumose over a little more than the proximal half of their lengths, the rest of the setae finely plumose, 1 bent dorsal seta visible in lateral view. Genital segment somewhat asymmetrical in dorsal (Fig. 1a) and ventral (Fig. 3g) views with a large ventrolateral projection extending left of the midline (Fig. 1c, 3f). First antenna at least as long as cephalothorax, of 20 segments. Second antenna (Fig. 1g) exopodite with 4 long terminal setae; endopodite with 5 terminal setae and a short dorsal seta midlength of distal segment; exopodite less than  $\frac{1}{2}$  as long as endopodite, 42% of endopodite length. Mandible (Fig. 1e) 1-branched as in *Arietellus*, with 4 long terminal setae on palp. Maxilla 1 (Fig. 1d) similar to *Arietellus*, 1st inner lobe with 5 spines, 1st outer lobe with 5 long and 3 shorter setae, endopodite and exopodite fused, with 3 long distal setae. Maxilla 2 (Fig. 2g) and maxilliped (Fig. 1h) similar in the 2 sexes, the longer setae furnished with augaptiloid cups. Leg 1 (Fig. 3a) endopod not clearly segmented into 3 joints. Leg 4 (Fig. 3j) lacks the plumose seta present on the 1st basipod segment of legs 1–3, but a rudimentary spinule may be present. Fifth legs (Fig. 3e) similar to those of female *P. buchani*, *P. meridionalis*, and *P. mozambicus*, with a long marginal and longer apical plumose seta, the marginal seta  $\frac{2}{3}$ rds the length of the apical one.

Male (Fig. 2a-j; Fig. 3b-d, h, k): 2.70–2.80 mm total length. Proportions of body and rostrum similar to female. Cephalothorax 77–78% of total length, with a sharp hook dorsally on each side of the last thoracic segment. Urosome 33–34% of cephalothorax length, segments covered dorsally with hairs. Caudal rami twice as long as wide with hairs laterally on each side. Second inner caudal seta much longer than others, setae pale plumose, lacking thick dark hairs characteristic of female. Right first antenna (Fig. 2b) of 20 segments, as long as cephalothorax; left (Fig. 2f) geniculate, of 19 segments, jointed between the 17th and 18th segments. Second antenna (Fig. 3c) differs from that of the female and resembles that of male *P. similis* in having a long seta dorsally midlength of last endopodite segment; exopodite relatively longer than in female, 49% of endopodite length, bearing distally a 5th shorter seta not present in female or in either sex of *P. buchani* or *P. similis*. Mandibular palp (Fig. 2e) differs from female's in having a long extra seta near base of last segment. Maxilla 1 and 2 and maxilliped as in female. Endopod of leg 1 clearly 3 segmented. Fifth legs (Fig. 2h) apparently most similar to those of male *P. mozambicus* (Gaudy, 1965, Fig. 7), last segment of left leg with a strong pincerlike spine and a weaker process of the same length, not bifid at tip as in *P. similis* and *P. buchani*.

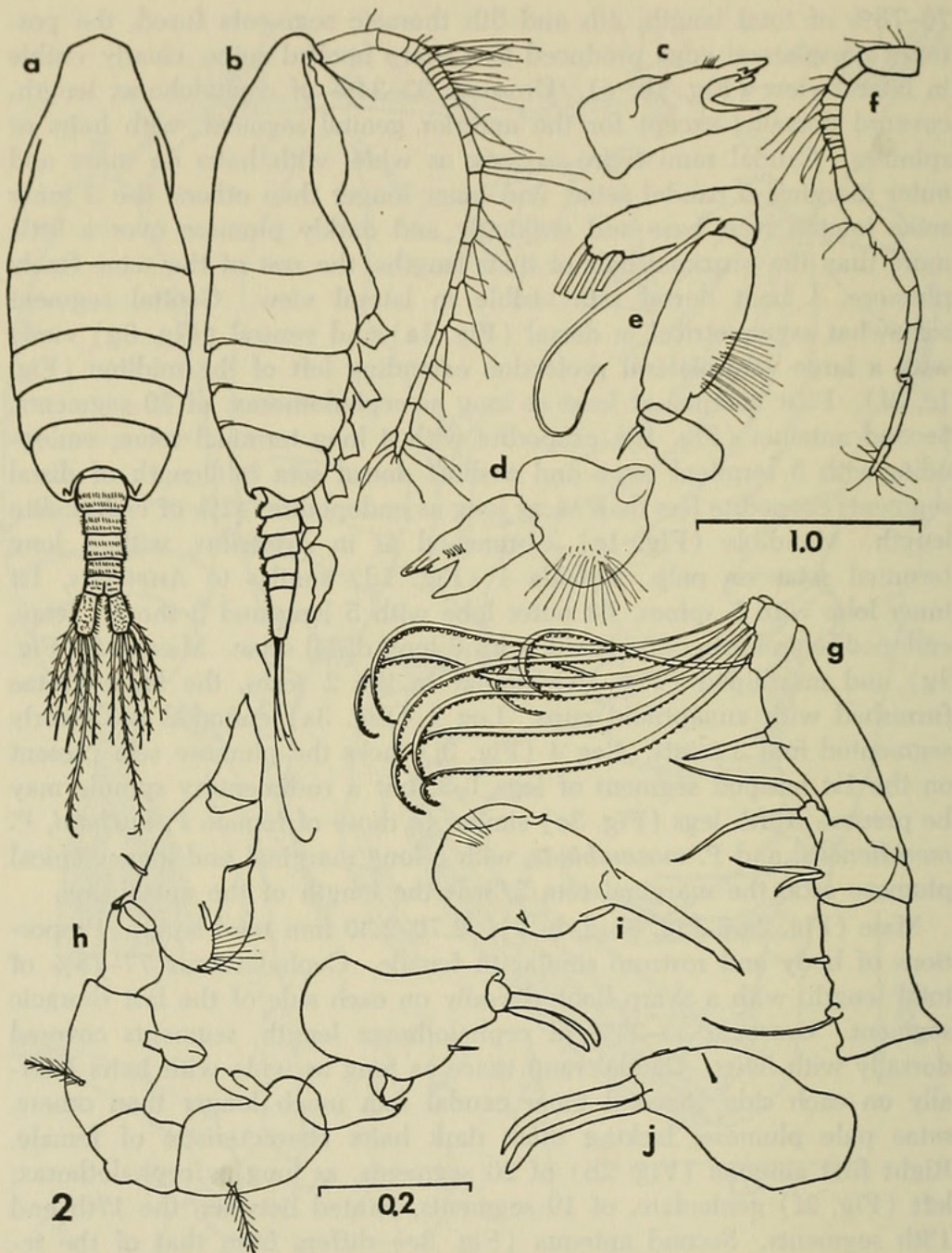


FIG. 2. *Paraugaptilus bermudensis*, new species, Male. a, and b, Dorsal and lateral views of male; c, d, Two views of mandible blade; e, Mandible palp; f, Left first antenna; g, Maxilla 2; h, Fifth legs; i, Another view of last segment of right 5th leg; j, Another view of last segment of left 5th leg. Scale at right center for a, b, f, at bottom for c-e, g-j. Scales in mm.

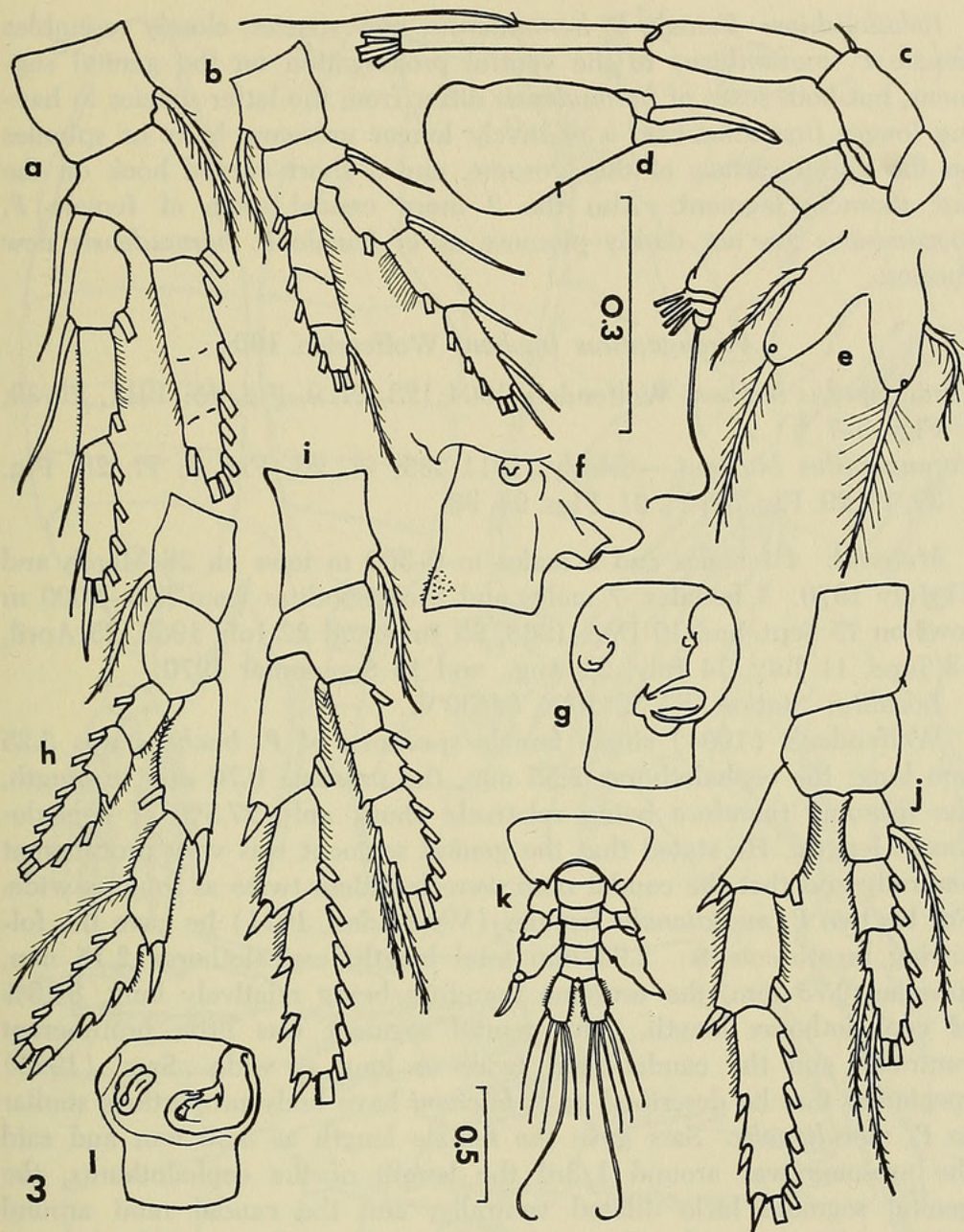


FIG. 3. *Paraugaptilus bermudensis*, new species, a, Female leg 1; b, Male leg 1; c, Male second antenna; d, Another view of last segment of male left 5th leg; e, Female 5th legs; f, g, Right lateral and ventral view of female genital segment; h, Male leg 2; i, Female leg 3; j, Female leg 4; k, Dorsal view of male urosome and 5th legs; l, Ventral view of genital segment of female *P. buchani* Wolfenden. Scale at bottom center for k, upper center for a-j, l. Scales in mm.

*Relationships:* Female *P. bermudensis*, new species, closely resembles female *P. mozambicus* in the ventral prolongation on the genital segment, but both sexes of *bermudensis* differ from the latter species in having longer first antennae, a relatively longer urosome, hairs or spinules on the dorsal surface of the urosome, and a short curved hook on the last thoracic segment. Also the 3 inner caudal setae of female *P. mozambicus* are not darkly plumose as in female *P. bermudensis* new species.

*Paraugaptilus buchani* Wolfenden 1904

*Paraugaptilus buchani* Wolfenden, 1904:123, Pl. 9, Fig. 45; 1911, Pl. 39, Figs. 5-7.

*Paraugaptilus buchani*.—Esterly, 1911:335, Pl. 26, Fig. 6; Pl. 28, Fig. 39; Pl. 29, Fig. 57; Pl. 31, Figs. 94, 98.

*Material:* 4 females and 2 males in 0-500 m tows on 28 March and 11 July 1970. 3 females, 7 males and 3 copepodites from 500-1,000 m tows on 15 Sept. and 19 Dec. 1968, 25 June and 22 July 1969, 25 April, 12 June, 11 July, 14 July, 21 Aug., and 15 September 1970.

*Locality:* Station "S", 32°10'N, 64°30'W.

Wolfenden's (1904) single female specimen of *P. buchani* was 3.25 mm long; the cephalothorax 2.55 mm, the urosome 0.70 mm in length, the urosome therefore being relatively short, only 27.5% of cephalothorax length. He stated that the genital segment was very protuberant ventrally and that the caudal rami were less than twice as long as wide. For his two *P. meridionalis* females (Wolfenden, 1911) he gave the following measurements: 2.90 mm total length; cephalothorax 2.15 mm, urosome 0.75 mm, the urosome therefore being relatively long, 34.8% of cephalothorax length. The genital segment was little protuberant ventrally, and the caudal rami twice as long as wide. Sars' (1925) specimens that he described as *P. buchani* have body proportions similar to *P. meridionalis*. Sars gave the female length as 3.30 mm and said the urosome was around 1/3rd the length of the cephalothorax, the genital segment little dilated ventrally, and the caudal rami around twice as long as wide. Because of the similarity between Sars' specimens and Wolfenden's *P. meridionalis* females, it is probable that Sars' (1924, 1925) description and figures are of *P. meridionalis*.

*Description:* Female (Fig. 3l, Fig. 4a-i): 3.00-3.20 mm total length. Head around 1/2 cephalothorax length, weakly fused with first thoracic segment, last segment with blunt tooth dorsally on each side. Urosome 30% or less of cephalothorax length; genital segment very slightly asymmetrical in dorsal view, dilated ventrally (Fig. 4i), developed asymmetrically ventrally on the left side (Fig. 3l). Caudal rami less than half as long as wide; with fine hairs laterally, caudal setae subequal, 2nd and 3rd inner setae jointed near base, finely plumose, short bent dorsal seta visible in lateral view. First antenna (Fig. 4c) of 21 segments, the 20th and 21st partially fused, reaching to genital segment.



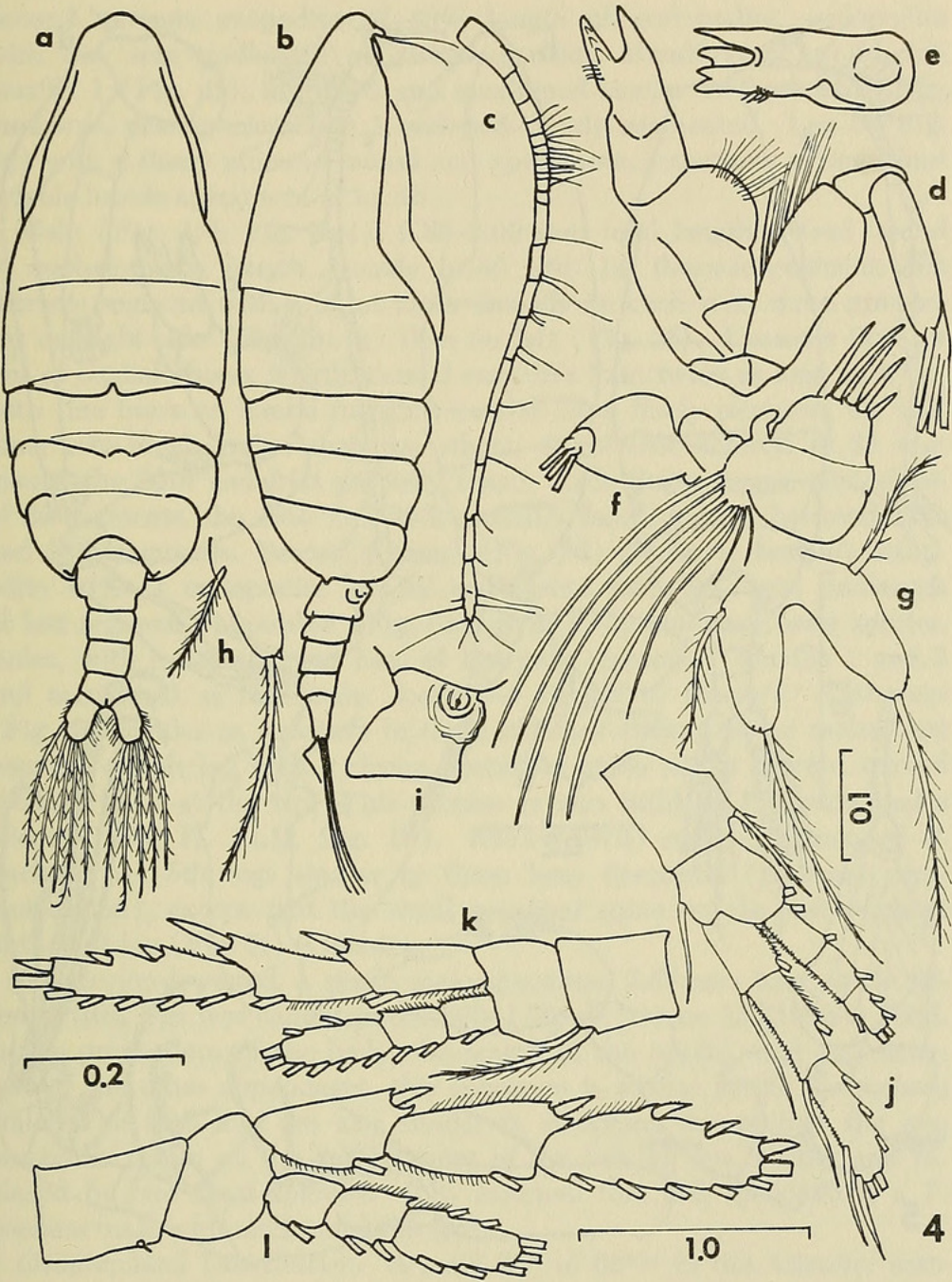


FIG. 4. *Paraugaptilus buchani* Wolfenden, a, b, Dorsal and lateral views of female; c, Female first antenna; d, Female mandible; e, Another view of mandible blade; f, Female maxilla 1; g, Female 5th legs; h, Lateral view of female 5th leg; i, Lateral view of female genital segment; j, Male leg 1; k, Male leg 2; l, Male leg 4. Scale at bottom right for a-c, on right margin for d-l. Scales in mm.

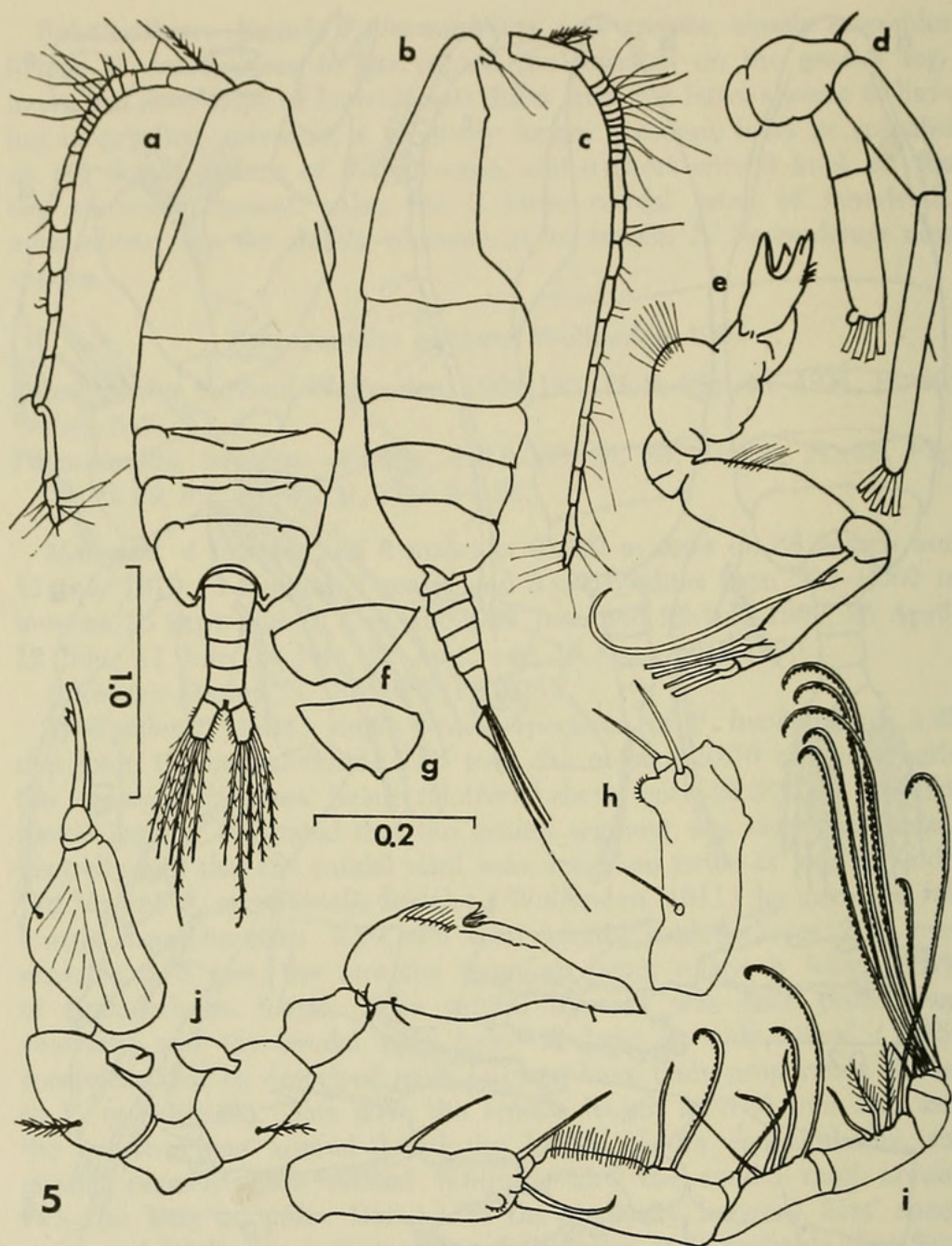


FIG. 5. *Paraugaptilus buchani* Wolfenden, Male. a, b, Dorsal and lateral views of male; c, Right first antenna; d, Second antenna; e, Mandible; f, Left side of last thoracic segment; g, Right side of last thoracic segment; h, Inner side of first segment of maxilliped; i, Maxilliped; j, Fifth legs. Scale at left for a-c, lower center for d-j. Scales in mm.

Second antenna exopodite 42–43% length of endopodite, endopodite with tiny seta midlength of distal segment. Mandible (Fig. 4d, e), maxilla 1 (Fig. 4f), maxilla 2 and maxilliped similar to those of *P. bermudensis*, new species. Leg 1 endopod clearly segmented. Leg 5 (Fig. 4g) with a finely plumose lateral and apical seta, sometimes a tiny blunt spinule beside apical seta (Fig. 4h).

Male (Fig. 4j-l; Fig. 5a-j); 2.85–3.00 mm total length. Head around  $\frac{1}{2}$  cephalothorax length, weakly fused with 1st thoracic segment; last thoracic segment with a blunt tooth dorsally on each side, more prominent on right side (Fig. 5b, g) than on left (Fig. 5f). Urosome 30% or less of cephalothorax length; caudal rami less than twice as long as wide, with fine hairs on lateral margins, caudal setae finely plumose, the 2nd inner seta much longer than the others. Right first antenna of 21 segments, the 20th and 21st partially fused. Left first antenna geniculate; of 20 segments, the 19th and 20th partially fused, jointed between 17th and 18th segments. Second antenna (Fig. 5d) similar to female's, exopodite 46% of endopodite length, endopodite with tiny seta midlength of last segment. Mandible (Fig. 5e) as in *P. bermudensis*, new species, males, with extra seta near base of last palp segment. Maxilla 1 and 2 and maxilliped as in female. Legs 1–4 similar to female's. Fifth legs (Fig. 5j) similar in structure to those of other *Paraugaptilus* males; last segment of left leg with a strong pincerlike spine and a shorter, curved process, bifid at the tip. This process is also bifid in *P. similis* males (Scott, 1909, Pl. XLII, Fig. 19). Roe's (1972) male specimen of *P. buchani* has 5th legs similar to those here described (personal communication), except that the small proximal spine on the last segment of the left leg (Fig. 5j) is missing.

As previously noted, a single male specimen, 2.85 mm long, with different fifth legs was caught in the 500–1,000 m tow on 15 October 1968. In the proportions of the body, the length of the caudal rami and structure of the other appendages, this specimen is similar to the *P. buchani* male. The fifth legs are also similar in structure, except that the two pincerlike spines on the last segment of the left leg are lacking and replaced by two short spinules. It is assumed that this specimen is a *P. buchani* male with malformed 5th legs.

*Geographical Distribution:* Around 28° to 60°N in the Atlantic; eastern Pacific off California coast.

#### DISCUSSION

The different species of *Paraugaptilus* have closely similar appendages. The fifth legs of female *P. buchani*, *P. meridionalis*, *P. mozambicus*, and *P. bermudensis*, new species, are apparently indistinguishable; only the *P. similis* female has somewhat different, slightly asymmetrical fifth legs. The male fifth legs differ primarily in the shape and relative lengths of the two pincerlike spines on the last segment of the left leg. The mouthparts are very similar. The species vary in the length of the first antenna

and caudal rami, the relative proportions of cephalothorax and urosome, the presence or absence of hairs or spinules on the cephalothorax and urosome, and the symmetry or degree of asymmetry of the female genital segment. Such asymmetry occurs in at least three species, *P. buchani*, *P. mozambicus* and *P. bermudensis*, new species, in that the left ventral side of the genital segment is more developed than the right.

The species of *Paraugaptilus* are also all of about the same size,  $\pm 3$  mm, the overall range in recorded length being 2.70 mm (*P. bermudensis*, new species, males) to 3.75 mm (Scott's *P. similis* females). The records indicate that all apparently live within the upper 1,000 m. In the Sargasso Sea most specimens were caught between 500 and 1,000 m depths, the region of the permanent thermocline, where temperature decreases with depth from 17° or 18°C to 7°C; a few specimens were found within the upper 500 m, especially in night tows. Gaudy's (1965) 22 specimens of *P. mozambicus* were caught between 300 and 400 m, where the temperature was 14°–15°C, although he later recorded immature specimens near the surface (1967). Lysholm, Nordgaard and Wiborg's (1945) specimens were taken at varying depths (200–500 m, 440–740 m or with 300–1,000 m of wire out) above 1,000 m. Vervoort's (1965) male was taken at around 600 m depth, Farran's (1908) female at 600 fathoms, Wolfenden's (1904) female at 300 fathoms, and Esterly's (1911) females at 315–320 fathoms. Roe's (1972) specimens were caught at 500 and 830 m depths. Other records are from open net hauls from 1,000–2,000 m to the surface.

The scarcity of records for *Paraugaptilus* must be due in part to the fact that the intermediate depths have been insufficiently sampled, but in addition the different species may have relatively restricted ranges, as suggested by Seymour Sewell (1948). Members of the genus are also rare, since, despite intensive sampling, *Paraugaptilus* was not commonly caught in the Sargasso Sea. Total estimated numbers, for the 500–1,000 m depth level, ranged from 5–77 specimens/1,000 m<sup>3</sup>. However, despite the paucity of numbers, the genus has a wide geographical distribution, having been recorded from around 23°S in the Indian Ocean off Madagascar, from 1°30'N in the Gulf of Guinea to 60°N in the Atlantic, and from about 54°N in the Pacific off the Alaska Peninsula to 10°N in the Philippines, and south of there in Indonesian waters between the Halmahera Sea at 0°17.6'S and the Banda Sea at 3°32.5'S.

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