

Three New Species of *Saccocirrus* (Polychaeta: Saccocirridae) from Hawai'i¹

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Abstract: Three new species of saccocirrids from interstitial sand habitats off O'ahu, Hawai'i, are described. Two are from subtidal depths, 9–33 m, and the third is from the intertidal to 3.5 m deep on a fringing reef and at Hanauma Bay, the Marine Life Conservation District and public park. The two deeper-water species, *Saccocirrus oahuensis*, n. sp. and *S. waianaensis*, n. sp., have 76–119 and 157–210 segments, respectively; they also have bilateral gonads but lack a pharyngeal pad. The third, *S. alanbongi*, n. sp., has 35–47 segments, unilateral gonads, and a muscular pharyngeal pad. These species are distinguished from 18 known *Saccocirrus* spp. by their unique chaetation, number of segments, presence or absence of ventral cilia, and pygidial adhesive structures. *Saccocirrus oahuensis* consumes foraminiferans, and *S. alanbongi* contained diatoms, unicellular algae, and ostracods. These species add to the interstitial fauna of O'ahu and cooccur with polychaetes *Nerilla antennata* (Nerillidae) and protodrilids (Protodrilidae), and Kinorhyncha. *Saccocirrus alanbongi* withstands almost daily disturbance by 600–1200 bathers per day entering the sandy swimming holes in the reef at Hanauma Bay.

SACCOCIRRIDES WERE FIRST recorded from Hawai'i in 1979, when they were found in sand on a shallow fringing reef near Pearl Harbor on the south shore of O'ahu, Hawai'i (Bailey-Brock 1979). This unnamed species from Fort Kamehameha reef was added to the polychaete fauna as *Saccocirrus* sp. in a revision of C. H. Edmondson's *Reef and Shore*

Fauna of Hawai'i (Bailey-Brock 1987). Saccocirridae were classified as "Archiannelida," which included Protodrilidae, Nerillidae, Dinophilidae, and Polygordiidae (Jouin 1971, Westheide 1985). This old grouping of five families has since been discarded (Westheide 1985, 1990) and all are families of Polychaeta. Westheide's papers emphasized the interstitial habitat as a unifying characteristic of eight families, including the five just listed and Protodriloidae, Diurodrilidae, and Parergodrilidae. Representatives of two families, *Mesonerilla fagei* and *Nerilla antennata* (Nerillidae) and *Protodrilus* sp. (Protodrilidae), are known from Hawai'i (Bailey-Brock 1987, 1999). Recently another protodrilid species, *Parenterodrilus* sp., was collected off Ni'ihau, Hawai'i, and awaits further study. In this paper we add three species of *Saccocirrus* collected from sand habitats in a shallow bay and on fringing reefs to depths of 35 m off O'ahu, Hawai'i.

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MATERIALS AND METHODS

Collections were made by hand with a corer 7.6 cm in diameter by 5 cm deep from 0.5- to 3.5-m depths in Hanauma Bay and from the seaward side of the intertidal reef flat at Fort

Kamehameha, bordering the entrance to Pearl Harbor. Scuba divers collected sediment cores of medium-grain calcareous sand off Wai'anae, and at Māmala Bay stations off the south shore of O'ahu. Those from greater depths (50 m or more) were taken with a van Veen grab deployed from a research vessel. All were preserved in 10% buffered formalin and Rose Bengal for 24 hr or more, elutriated over 0.50- and 0.25-mm mesh sieves, and stored in 70% ethanol. Preserved specimens were mounted in glycerol on slides and examined with phase contrast and dark and bright field microscopy. Magnifications for line drawings made with a compound microscope with 10× eyepieces are from 40 to 1000× with oil. Specimens of the three species were examined with scanning electron microscopy (SEM) using a field emission microscope (Hitachi S-800) operating at 15 KV after ethanol dehydration and coating with gold-palladium. Specimens of *S. alanhongi* were dried with a critical point drier (Autosamdri-810). Specimens of the other species were air dried on parafilm in a desiccator because the drier required extensive repair or replacement. Micrographs were saved as TIFF images and prepared as plates with Adobe Photoshop.

RESULTS

Three new species of Saccocirridae Czeriavsky, 1881, found in sand collected from the south, east, and west shores of O'ahu are described here. Numerous specimens of *Saccocirrus alanhongi* were collected in sand from Hanauma Bay (southeastern O'ahu) on 27 July 1999, and they were abundant (483 specimens) in coarse sands at Fort Kamehameha reef flat (southern O'ahu) collected in 1977 (Bailey-Brock 1979). Specimens of *Saccocirrus oahuensis* were collected in sediments adjacent to four O'ahu sewage outfalls: Wai'anae on the west, Sand Island and Barbers Point on the south, and Mōkapu on the east. Four specimens of *Saccocirrus waianaensis* were found off the Wai'anae sewage outfall, three off the sandy beach fronting Waimānalo on the east coast of O'ahu, and one off Hilo Bay, Hawai'i.

Saccocirrus alanhongi Bailey-Brock, Dreyer & Brock, n. sp.
Figures 1–4

TYPE MATERIAL: Holotype: USNM 1012494, Hanauma Bay, O'ahu, Hawai'i, at depths of 0.5–3.5 m, 27 July 1999. Paratypes: USNM 1012495–1012497, same data as holotype.

DESCRIPTION: Specimens measure 2.7–3.4 mm in length and 0.25–0.30 mm in width. Number of segments ranges between 35 and 47 (Figure 1A). One pair of long, wrinkled cephalic tentacles measuring 0.40–0.72 mm extends about one-third of the body length (Figure 1B–D). The first 1 or 2 segments and posterior segments 3–11 are achaetous. One pair of red eyes is present on the rounded prostomium (Figure 1B). Eyes present as ciliary patches (Figure 3A,B). Nuchal organs are a dorsal groove between prostomium and peristomium (Figures 1B,C; 2A; 3A,B). A muscular pharyngeal pad (Figure 1B) and ventral mouth (Figures 1D, 2A–C) are present. Cilia are on the ventral surface of the prostomium (Figure 2A,B), around the mouth (Figure 2A–D), and in the midline to the third chaetiger (Figure 2A,B). Paddlelike cilia around the mouth may be actual features or artifacts of specimen preservation (Figure 2D). Parapodia are uniramous with 3 types of chaetae per fascicle (Figures 1G, 3C, 4A). The first type is longest, having a terminal fork with unequal branches and a short, serrated median projection that gives a tridentate appearance at 100× oil, 1 or 2 per fascicle (Figures 1G,H; 3C,D). The median region is composed of 6 short, digitiform projections (Figure 3D); one in the middle is longer and broader than the others. The second type is a medium-length forked chaeta with equal-length prongs; margins in the fork appear smooth at 100× oil (Figure 1G), but 4–6 serrations along the distal part of the inner margins are visible with SEM (Figure 4A), 3 per fascicle. The third type is a short, simple chaeta with a terminal notch, 2–3 per fascicle (Figures 1G; 4A,C). Clusters of 3 peglike structures and a few single apertures (Figure 4B) were evident across the ventrum of anterior segments. Pegs are possibly solidified adhesive material and the holes remain

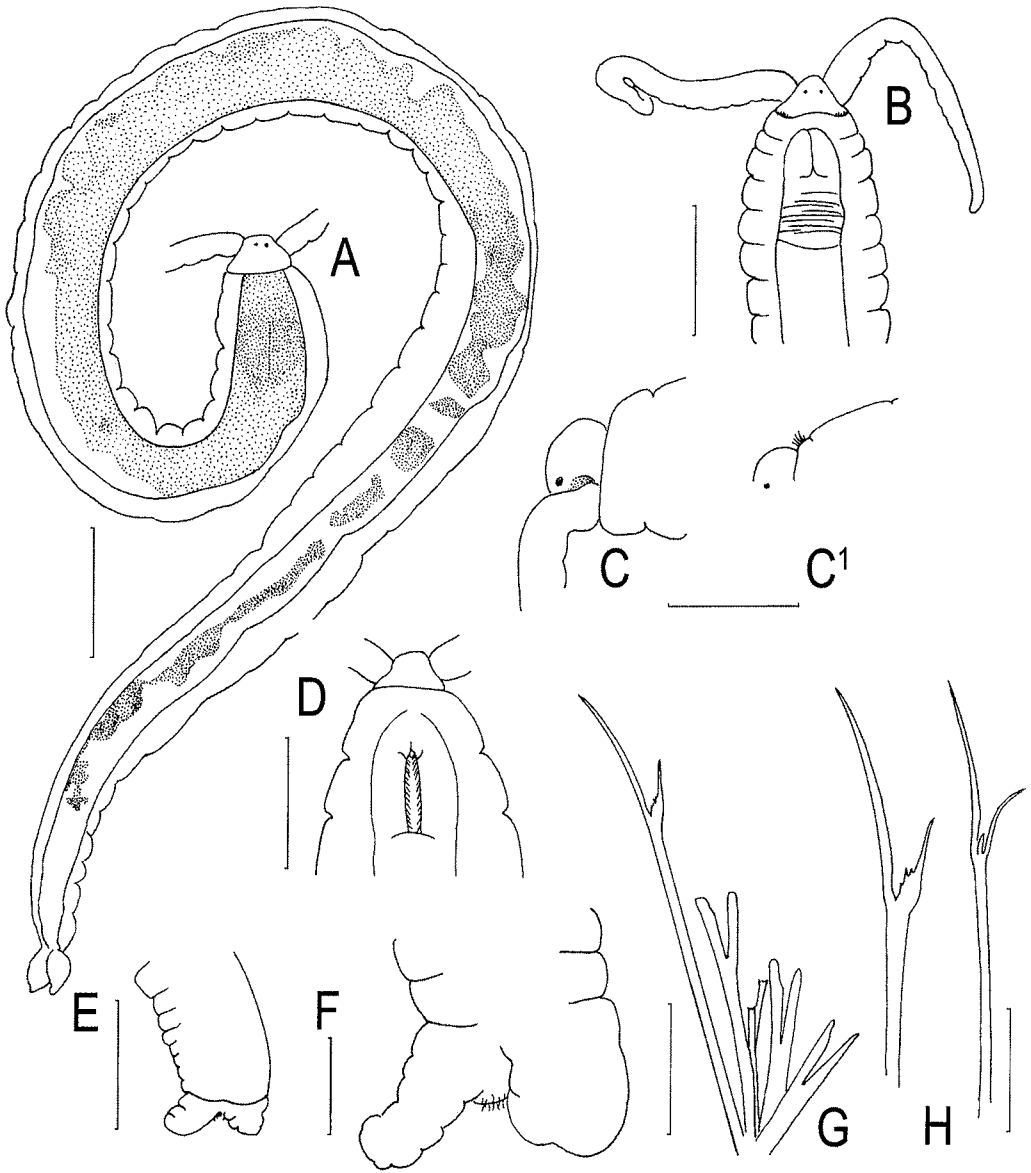


FIGURE 1. *Saccocirrus alanbongi*. A, Entire worm, dorsal to lateral view; B, anterior, dorsal view, prostomium, peristomium, cephalic tentacles, apertures of nuchal organs, pharyngeal pad; C, anterior, lateral view, groove defining nuchal organs; C¹, nuchal organ cilia; D, anterior, ventral view; E, F, papillate pygidium; G, three types of chaetae; H, long chaetae (G, H 100× oil). Scales: A, 0.2 mm; B, C, C¹, D, 0.1 mm; E, 0.2 mm; F, 0.05 mm; G, 0.01 mm; H, 0.02 mm.

when the material is extruded. Gonads are assumed to be unilateral due to the presence of the pharyngeal pad, and one specimen was collected with eggs on one side of the gut. Pygidium bifurcated (trifurcated in 1 speci-

men), lobes 0.06–0.15 mm in length, each lobe with 4–6 ridges with adhesive papillae on the inner surface, without anal cirri (Figures 1E,F; 4D).

REMARKS: Long chaetae resemble those

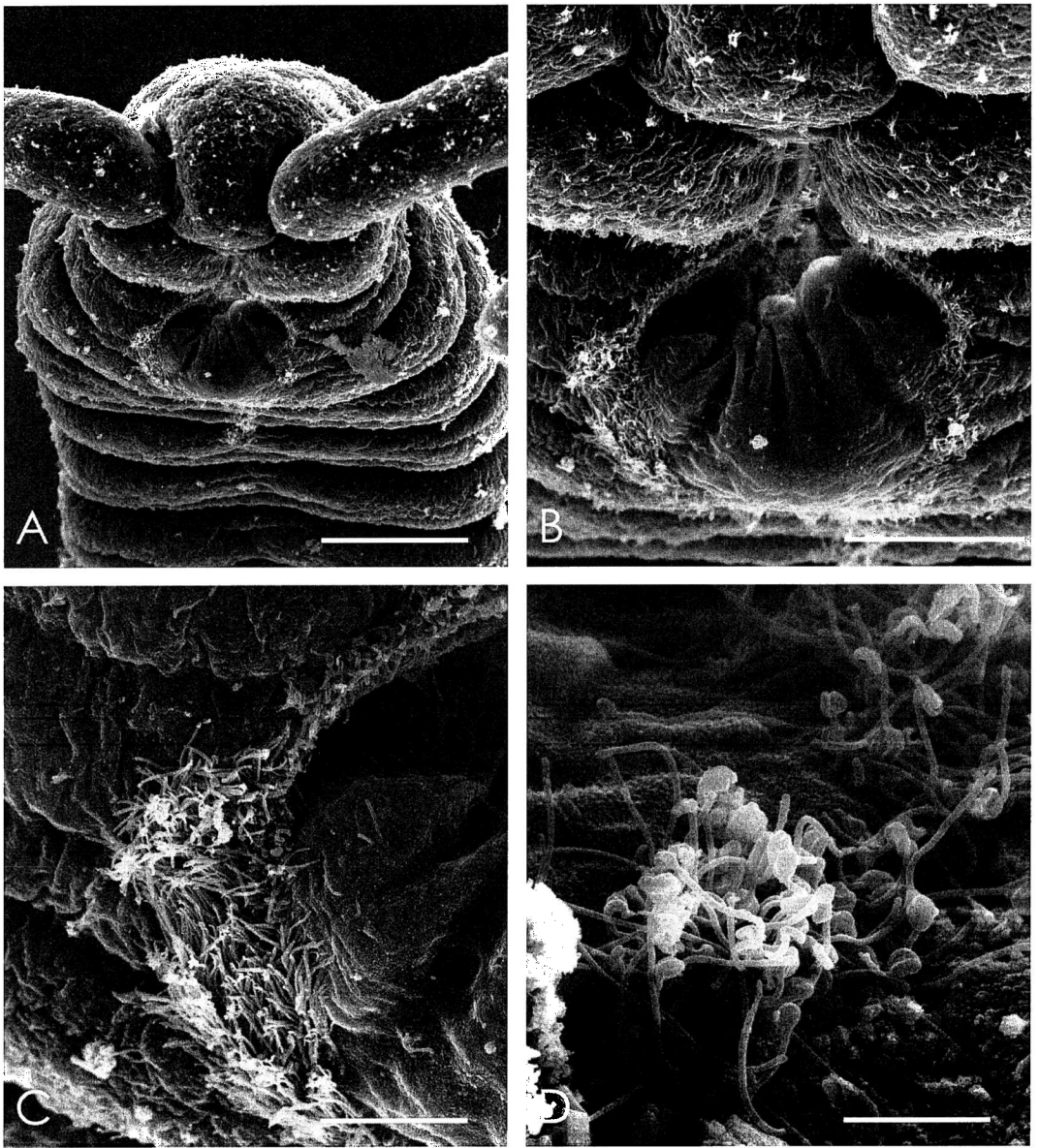


FIGURE 2. Scanning electron micrographs of *Saccocirrus alanbongi*. *A*, Anterior region, view of cephalic tentacles, nuchal organs, and mouth; *B*, mouth surrounded by cilia, ventral groove cilia, and folded oral membrane; *C*, peristomial cilia and oral membrane; *D*, paddlelike peristomial cilia (see text for discussion). Scales: *A*, 60 μm ; *B*, 30 μm ; *C*, 10.0 μm ; *D*, 3.8 μm .

of *Saccocirrus tridentiger* Brown, 1981, but the Australian species has a curved short branch and three chaetae per fascicle whereas *S. alanbongi* has only one long chaeta (in one rare occurrence observed only in SEM, two

were present). Medium chaetae number two to four in *S. tridentiger* and two to three in *S. alanbongi*. Pygidial adhesive papillae differ: *S. tridentiger* has 6–14 papillar ridges, and the Hawaiian species has four, rarely six. *Saccocir-*

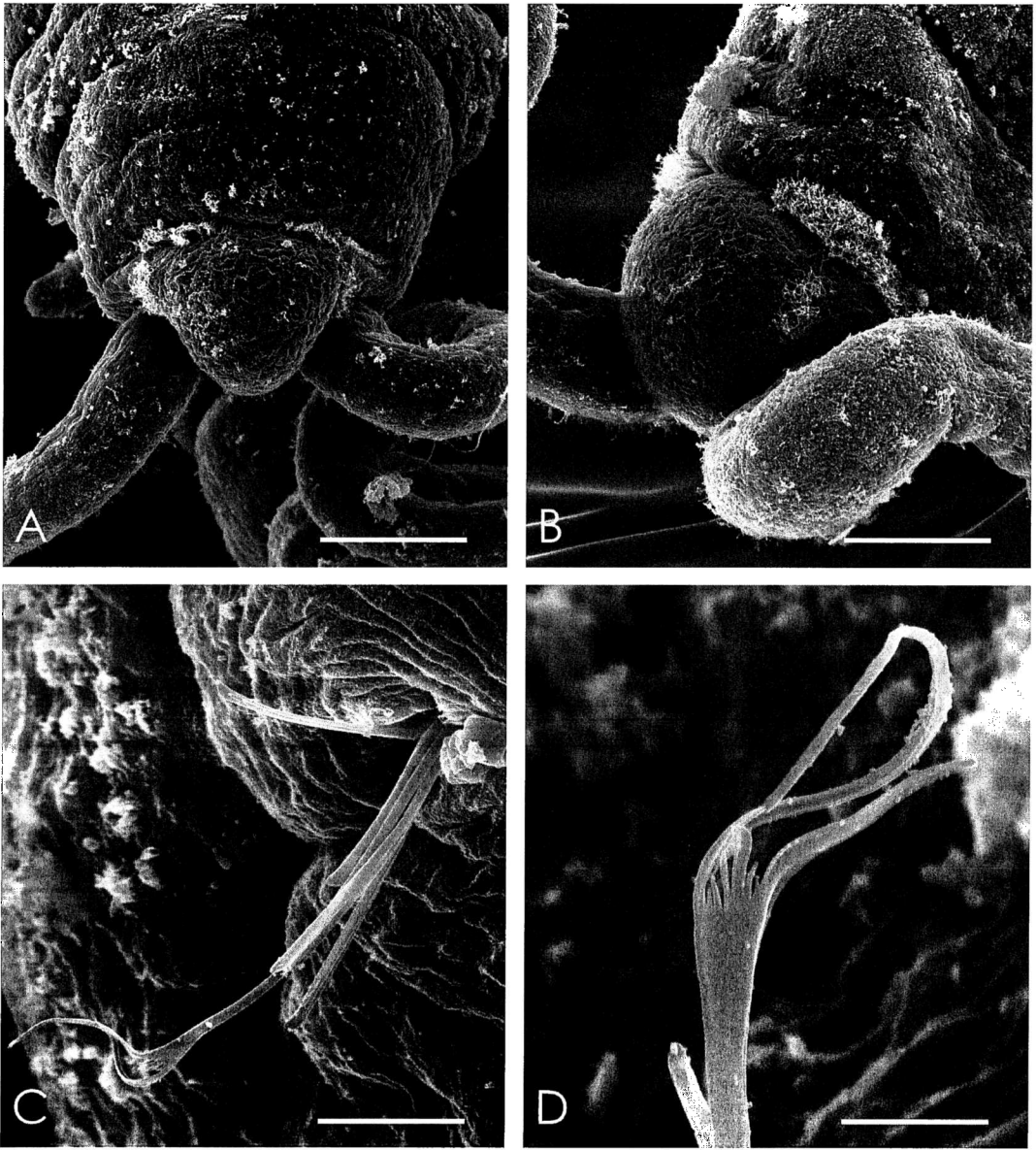


FIGURE 3. Scanning electron micrographs of *Saccocirrus alanbongi*. A, Anterior region, dorsal view; B, anterior region, lateral view showing nuchal organs and left eye; C, fascicle with three kinds of chaetae; D, long chaeta. Scales: A, 60 μm ; B, 43 μm ; C, 8.6 μm ; D, 3.0 μm .

rus alanbongi is substantially smaller (up to 3.4 mm) with fewer segments (up to 47) than the Australian species, which has 62–98 segments measuring up to 20 mm. Ciliation of the midventral groove to chaetiger 8 is present in

S. tridentiger; *S. alanbongi* has ventral ciliation below the mouth to the third chaetiger and cilia on the prostomium and peristomium near the mouth. It differs from *Saccocirrus krusadensis* Alikunhi, 1948, from India, which

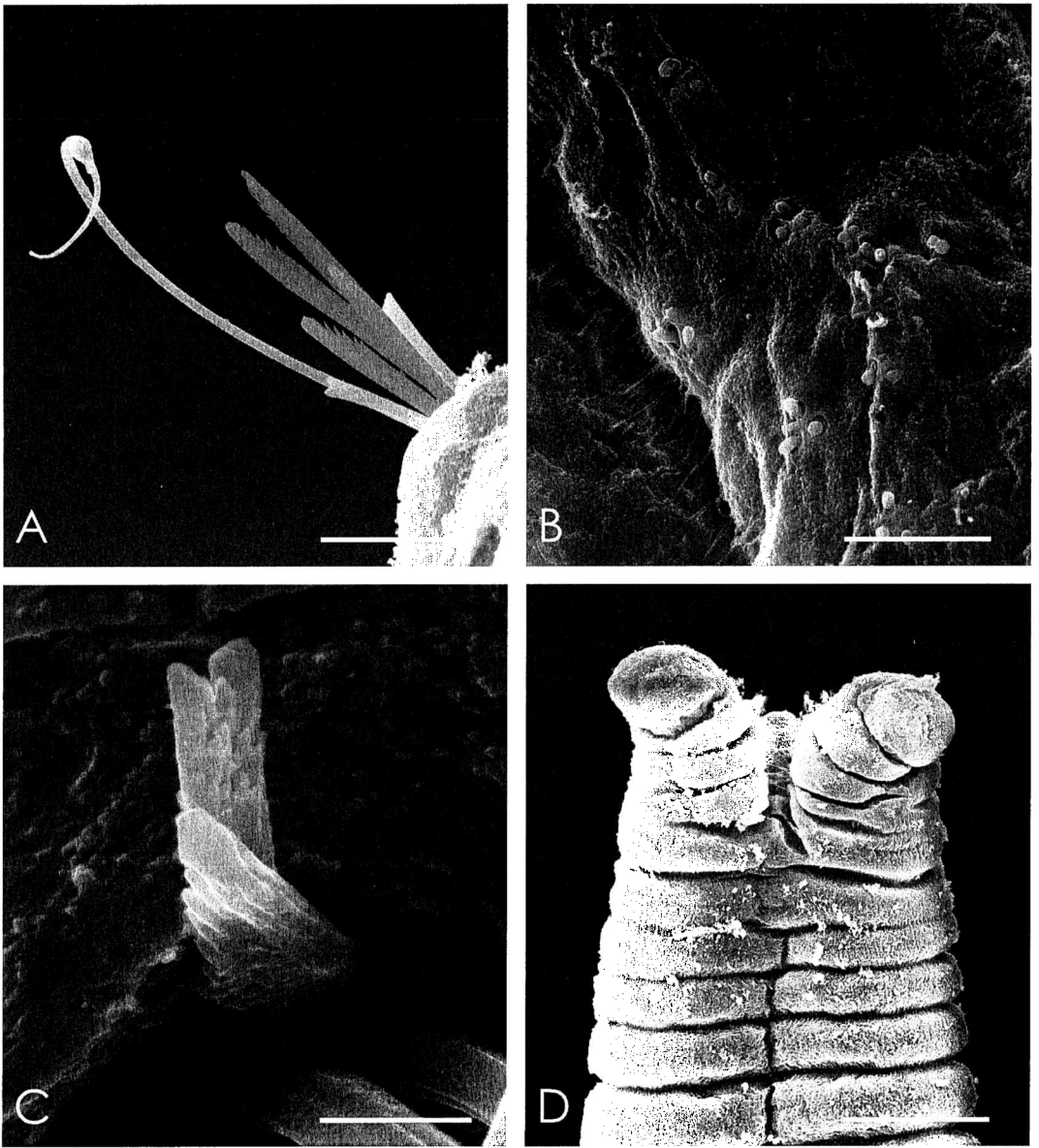


FIGURE 4. Scanning electron micrographs of *Saccocirrus alambongi*. A, Serrate inner margins of forked chaetae; B, peg structures and apertures across ventrum; C, short chaetae; D, pygidium and adhesive papillae. Scales: A, 10.0 μm ; B, 7.5 μm ; C, 1.5 μm ; D, 50 μm .

lacks the middle prong in the long chaetae (also not present in *S. krusadensis* from Australia). The long chaetae of *S. alambongi* are very similar to those of *S. krusadensis* from Laccadive and Moorea (Jouin and Rao 1987).

The forked chaetae of *S. krusadensis* from India have obvious serrations on the inner margin (at 1750 \times in Alikunhi 1948, fig. 2*b*), like those shown with SEM from Laccadive, Moorea, and Durban (Jouin and Rao 1987).

The serrations in *S. alanbongi* chaetae are confirmed only with SEM. Curvature and flat plane of chaetae are often distorted in SEM preparation. Tips of long bifurcate chaetae twist; fork branches of forked chaetae may fold against each other or each branch twist into a spiral; and the serrate margin rolls into the fold to appear asymmetrically serrated compared with the other fork. *Saccocirrus krusadensis* has 100–150 segments and measures 20–25 mm; *S. alanbongi* has only up to 47 segments and measures 2.7–3.4 mm. The Moorea *S. krusadensis* has more papillar ridges and longer pygidial lobes than *S. alanbongi*. *Saccocirrus alanbongi* is distinguished from these other two species based on (1) body size, (2) number of segments, (3) extent of the midventral groove ciliation, (4) pygidial lobe length, and (5) number of papillar ridges.

MATERIAL EXAMINED: Thirty or more specimens from Hanauma Bay and four specimens from Fort Kamehameha intertidal reef flat (Bailey-Brock 1987). Five specimens from Hanauma Bay were measured and segments counted, and five were examined with SEM.

ETYMOLOGY: *Saccocirrus alanbongi* is named for Alan Hong, Department of Parks and Recreation, City and County of Honolulu, lifelong caretaker of Hanauma Bay.

Saccocirrus oahuensis Bailey-Brock, Dreyer & Brock, n. sp.
Figures 5, 6

TYPE MATERIAL: Holotype: USNM 1012490, Māmala Bay station 4 (station designations are given in Swartz et al. 2002), 21° 17' 07" N, 158° 05' 28" W at 9.4-m depth near Barbers Point, O'ahu, Hawai'i, 11 August 2001. Paratypes: USNM 1012491, same data as holotype.

DESCRIPTION: Specimens measure 8.40–10.45 mm in length and 0.3–0.4 mm in width. One pair of lightly articulated cephalic tentacles measuring 1.25–1.4 mm in length (Figure 5A–C) is present. Number of body segments ranges between 76 and 119. The first segment is achaetous (except in one specimen where the first 3 segments were achaetous), and 5–8 posterior segments are achaetous. One pair of red eyes is present on

the bluntly rounded prostomium (Figure 5A). Nuchal organs are present in some specimens (Figure 5B) but are not easily observed with light or scanning microscopy. Cilia were not visible on the head or anterior segments (Figure 6A). Without a muscular pharyngeal pad. Parapodia are uniramous with 3 types of chaetae in each fascicle (Figures 5I; 6B–D). The first type is the longest, having an asymmetrical bifid tip, 1 per fascicle (Figure 6B). The second type is a medium-length forked chaeta (Figure 6C,D) with 2 inner points, 3–4 per fascicle (Figure 5I). The third type is a short, blunt-tipped simple chaeta with small apical teeth, 3 per fascicle. Gonads are bilateral, and eggs are present in all type specimens. Two developmental stages, based on egg size, were seen. Pygidium bifurcated (Figures 5D–H; 6C,D), lobes 0.14–0.20 mm in length, each lobe with 5–6 ridges with adhesive papillae on the inner surface (Figure 5D–H). Pygidium with anal cirri (Figure 5E,F) in some specimens examined (1 specimen illustrated without anal cirri [Figure 5H]). The anal cirri detached from the dried specimens during mounting for SEM (Figure 6E). Pygidial palpcils are visible in others (Figure 5G,G¹). Tufts of cilia were seen on the pygidium and posterior achaetous segments and on the palpcils (Figure 5G¹).

REMARKS: *Saccocirrus oahuensis* resembles *Saccocirrus cirratus* Aiyar & Alikunhi, 1944, *S. parvus* Gerlach, 1953, and *Saccocirrus minor* Aiyar & Alikunhi, 1944: all three have bilateral gonads and somewhat similar chaetae. It differs from them in the structure of long chaetae, which terminate as broad, blunt chisels in *S. minor* and bifid chaetae with unequal blunt tips in *S. cirratus* and *S. parvus*. In *S. oahuensis* one arm of the bifid tip is longer and the width of each arm is less than in the other species. Medium chaetae of *S. oahuensis* are forked, with a pair of needlelike points in the crotch of the fork and an incision (Figure 6D). Medium chaetae of the other species have blunt tips without a fork or incision. Size and number of segments vary in all four species, with *S. oahuensis* being intermediate, measuring up to 10.45 mm long with 119 segments. In contrast, *S. cirratus* measures 40–45 mm long with up to 200 segments, *S.*

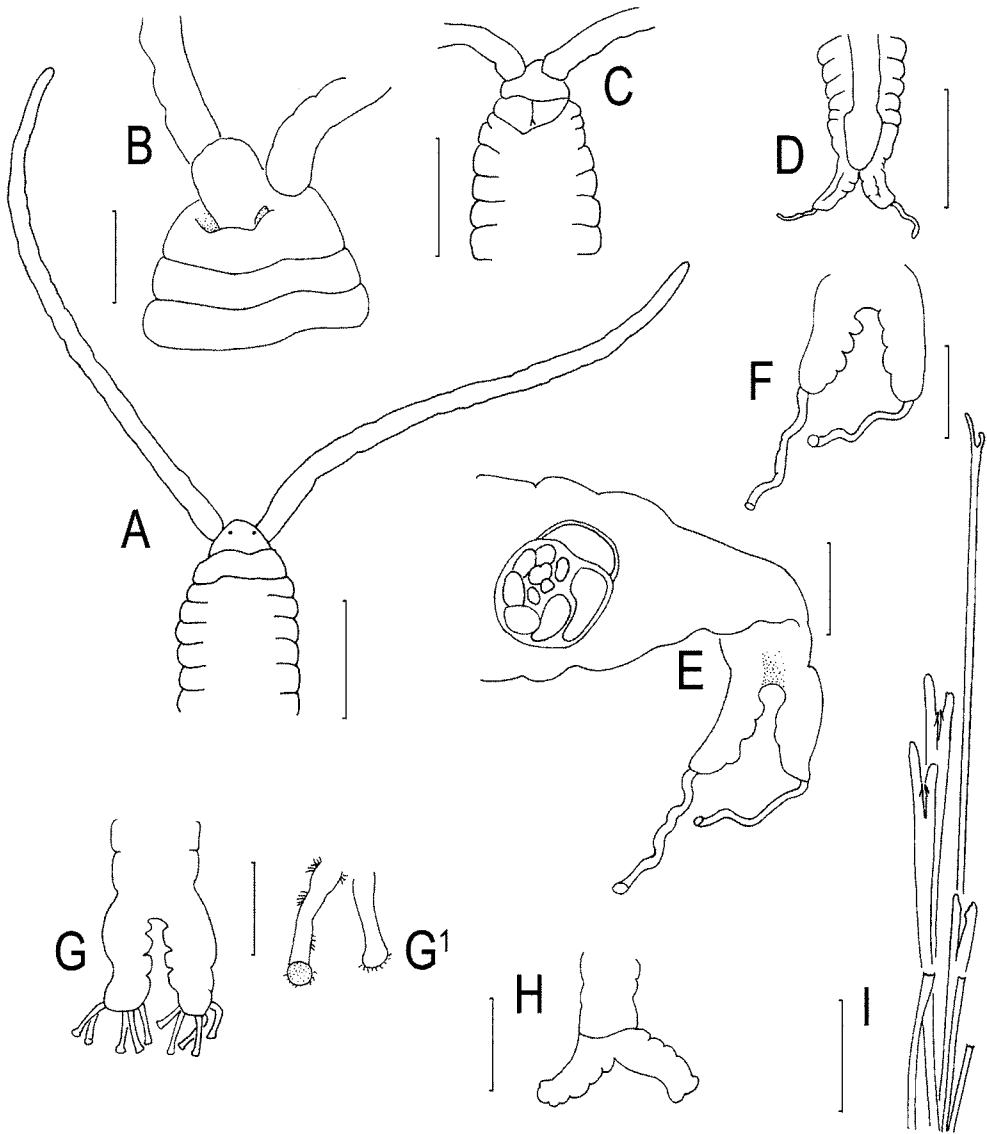


FIGURE 5. *Saccocirrus oahuensis*. A, Anterior region, dorsal view; B, anterior, lateral view, cephalic tentacles and nuchal organs; C, ventral view, position of the mouth; D, bifurcate pygidium with anal cirri; E, posterior region with a foraminiferan in the gut; F, pygidium with papillae and anal cirri; G, pygidium with extruded palpcirri; G¹, palpcirri with swollen tips and tufts of cilia; H, pygidium of specimen missing anal cirri; I, three types of chaetae. Scales: A–D, 0.02 mm; E, 0.075 mm; F, 0.02 mm; G, 0.02 mm; G¹, enlargement of G; H, 0.02 mm; I, 0.05 mm.

minor measures 10–15 mm long with 70–100 segments, and *S. parvus* measures 2.5–3.0 mm long with up to 48 segments. *Saccocirrus cirratus* has a muscular pharyngeal pad, but *S. oahuensis* does not. *Saccocirrus cirratus* has ex-

panded pygidial lobes with adhesive margins without papillae but possesses long, slender anal cirri; *S. parvus* has broad pygidial lobes without papillae; and *S. minor* lacks or has very reduced pygidial lobes and no papillae (Aiyar

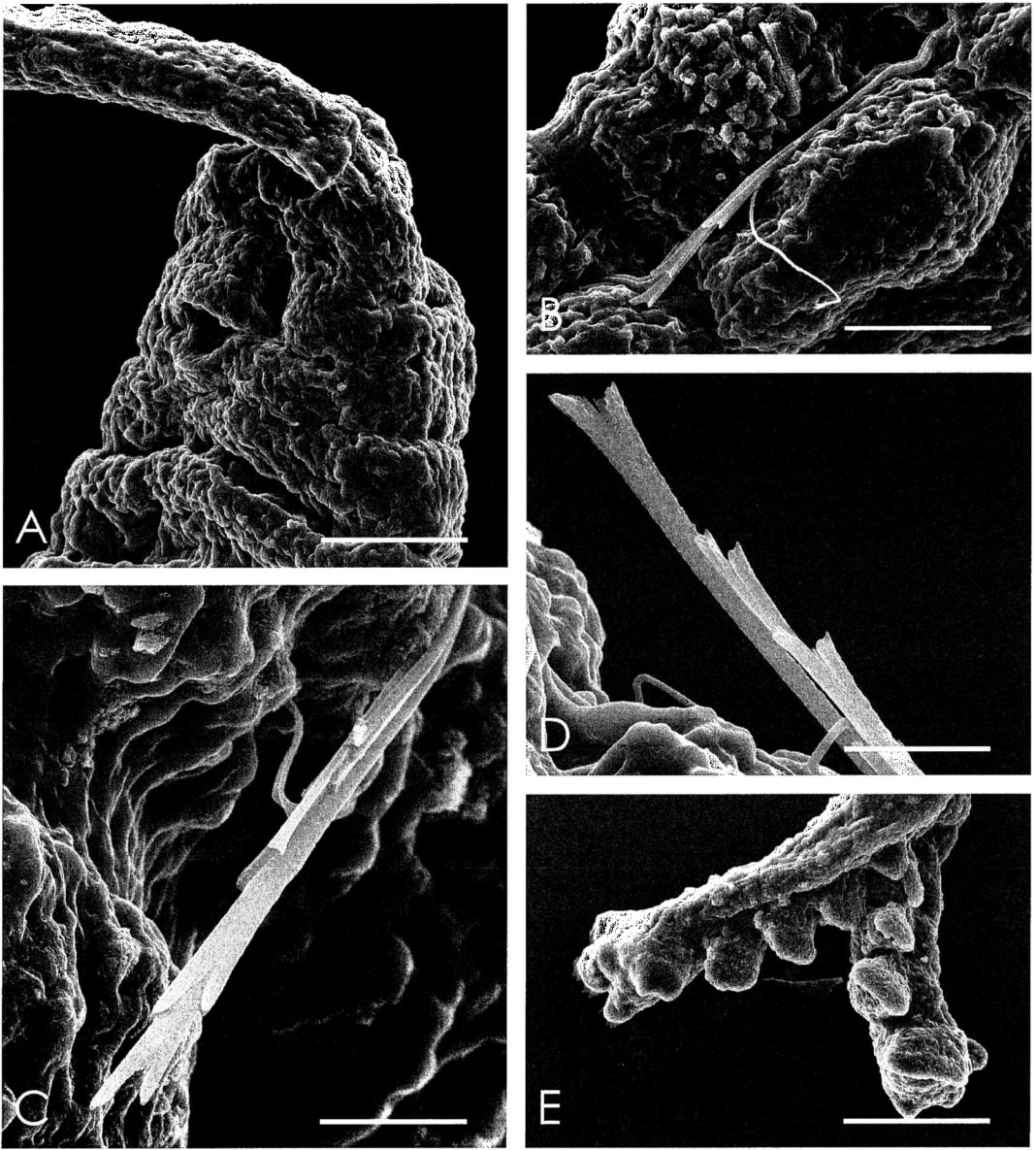


FIGURE 6. Scanning electron micrographs of *Saccocirrus oahuensis*. *A*, Anterior region, ventrolateral view showing mouth and absence of cilia; *B*, fascicle showing a slender long chaeta (bent) and stout forked chaetae; *C* and *D*, short and forked chaetae; *E*, pygidial lobes with adhesive papillae (cirri lost in preparation). Scales: *A*, 50 μm ; *B*, 38 μm ; *C*, 12.0 μm ; *D*, 12.6 μm ; *E*, 43 μm .

and Alikunhi 1944, Jouin and Rao 1987). In contrast, *S. oahuensis* has five to six pygidial papillae and short anal cirri or palpcocils.

MATERIAL EXAMINED: More than 35 specimens from Māmala Bay and Mōkapu.

Five specimens were measured and segments counted, and five were examined with SEM.

ETYMOLOGY: *Saccocirrus oahuensis* is named for O'ahu, the island where the city of Honolulu and Waikīkī Beach are located.

Saccocirrus waianaensis Bailey-Brock, Dreyer & Brock, n. sp.
Figures 7–10

TYPE MATERIAL: Holotype: USNM 1012492, sand sediments adjacent to Wai'anae ocean outfall station W1R2 (station designations are given in Russo et al. 1997), O'ahu, Hawai'i, at 31.4-m depth, 13 May 2001. Paratypes: USNM 1012493, same locality as holotype but from station W9R4 at 32.9-m depth, 20 July 1997.

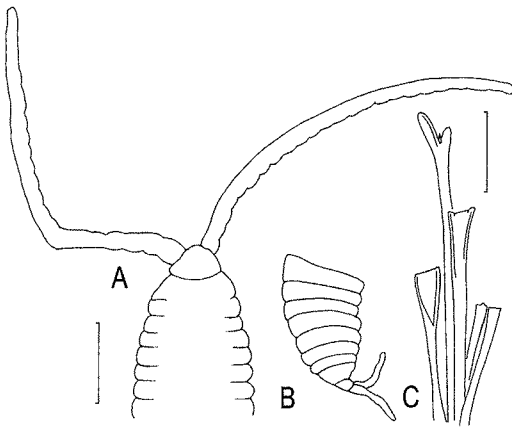


FIGURE 7. *Saccocirrus waianaensis*. A, Anterior region, dorsal view; B, posterior with bifurcate pygidium; C, three types of chaetae. Scales: A, B, 0.01 mm; C, 0.02 mm.

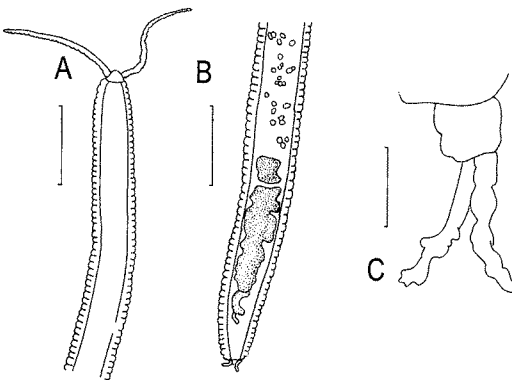


FIGURE 8. *Saccocirrus waianaensis*. A, Anterior region, dorsal view; B, middle and posterior regions with eggs and gut contents indicated (shaded); C, pygidium with anal cirri. A and B are of the same specimen. Scales: A, B, 0.2 mm; C, 0.1 mm.

DESCRIPTION: Specimens measure 8.4–10.0 mm in length and 0.33–0.45 mm in width (Figures 7A; 8A,B). Number of body segments ranges from 157 to 210. There is 1 pair of lightly articulated cephalic tentacles measuring 0.90–1.31 mm in length (Figures 7A, 8A). There are no anterior achaetous segments, but 5–9 posterior achaetous segments are present. Prostomium is rounded. Eyes were not observed in these specimens (Figures 7A, 8A). Nuchal organs, a muscular pharyngeal pad, and ventral cilia patches were not observed with light microscopy or SEM (Figure 9A,B). Lower lip of mouth on the ventral surface is crenulated (Figure 9B). Parapodia uniramous with 3 types of chaetae (Figures 7C; 9C; 10A,B,D). The first type is the longest (but its length is intermediate in comparison with long chaetae of *S. oahuensis* and *S. alanbongi*) with an unequal trifid tip (Figure 9C), with the median arm being the shortest, 1 chaeta per bundle. These trifid chaetae are longest in posterior segments (88–96). The second type is a sturdy symmetrical forked chaeta, intermediate in length, deeply incised, with distal margins of the fork appearing smooth, and a hood reaching across both arms of the fork (Figures 7C; 10C). There are 1 or 2 forked chaetae per fascicle. The third type is the shortest, with 2 small apical teeth, with 2–3 per fascicle (Figures 7C; 9D). The pygidium is bifurcate and bears 2 anal cirri from 0.08 to 0.25 mm in length (Figures 7B; 8C). No distinct adhesive papillate ridges are obvious, but anal cirri are slightly articulated (Figure 8C). Reproductive characters were observed in the paratype only. Gonads are bilateral. The number of eggs in each reproductive segment varied (Figure 8B).

REMARKS: Chaetae resemble those of *S. parvus* from the Gulf of Naples (Gerlach 1953). In *S. parvus* the longest is bifurcate with branches of unequal length but lacks the median spine seen in *S. waianaensis*. There are similarities to the shape of the medium-length chaetae of *S. minor* from India (Aiyar and Alikunhi 1944) and *S. parvus*, but these two species lack the fork or incision that is clearly present in *S. waianaensis*.

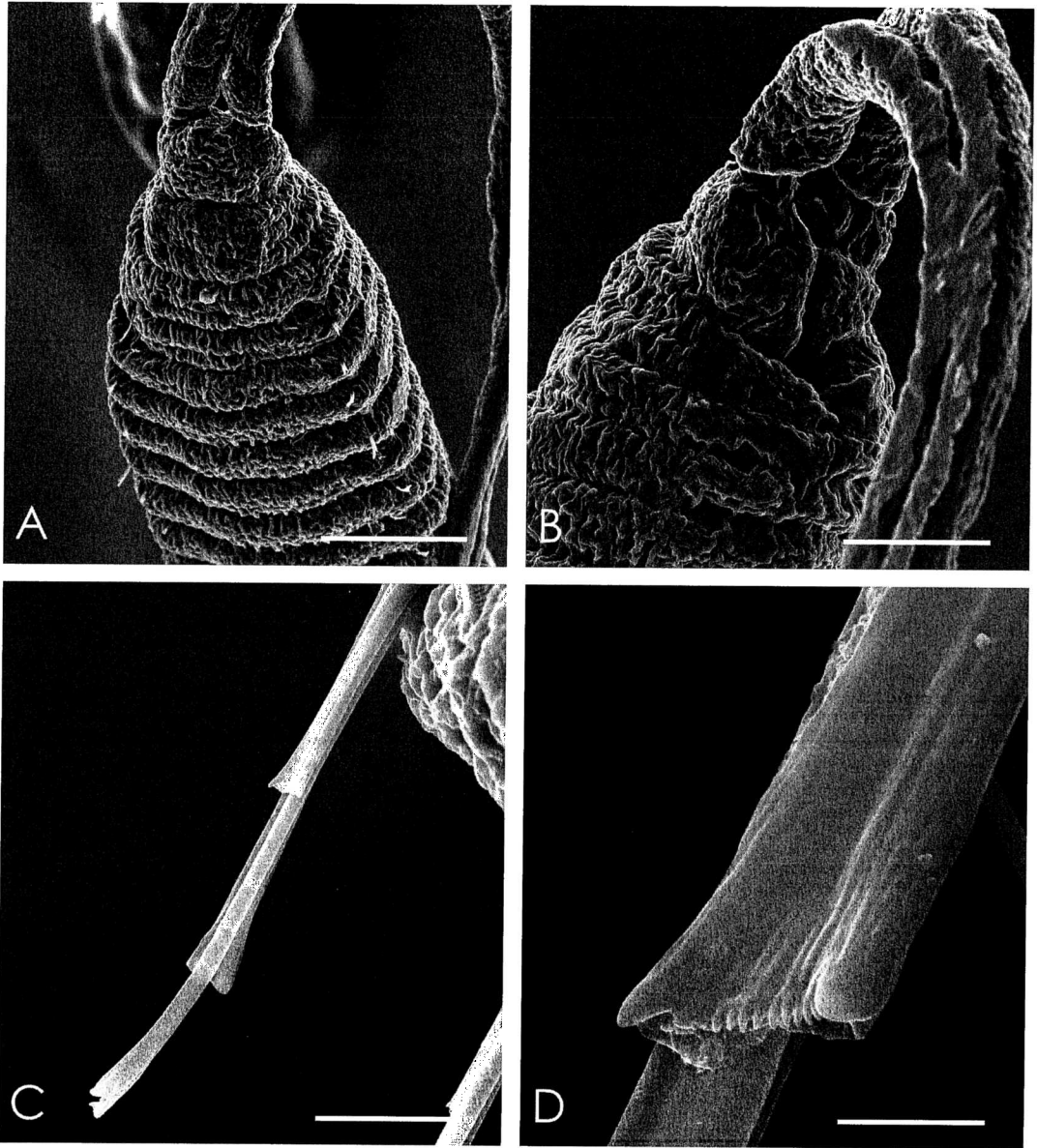


FIGURE 9. Scanning electron micrographs of *Saccocirrus waianaensis*. *A*, Anterior region, dorsal view, showing segments and chaetae; *B*, anterior region, lateral view, with mouth and absence of cilia; *C*, fascicle with three chaetae; *D*, finely toothed terminal margin of chaeta. Scales: *A*, 100 μm ; *B*, 60 μm ; *C*, 13.6 μm ; *D*, 2.5 μm .

MATERIAL EXAMINED: Four specimens from Wai'anae were measured and segments counted, and two specimens were examined with SEM. Eyes were not seen; they may be

minute and inconspicuous, as described for *S. cirratus*, or hard to distinguish due to lengthy storage in ethanol. Three specimens collected more recently from Waimānalo in eastern

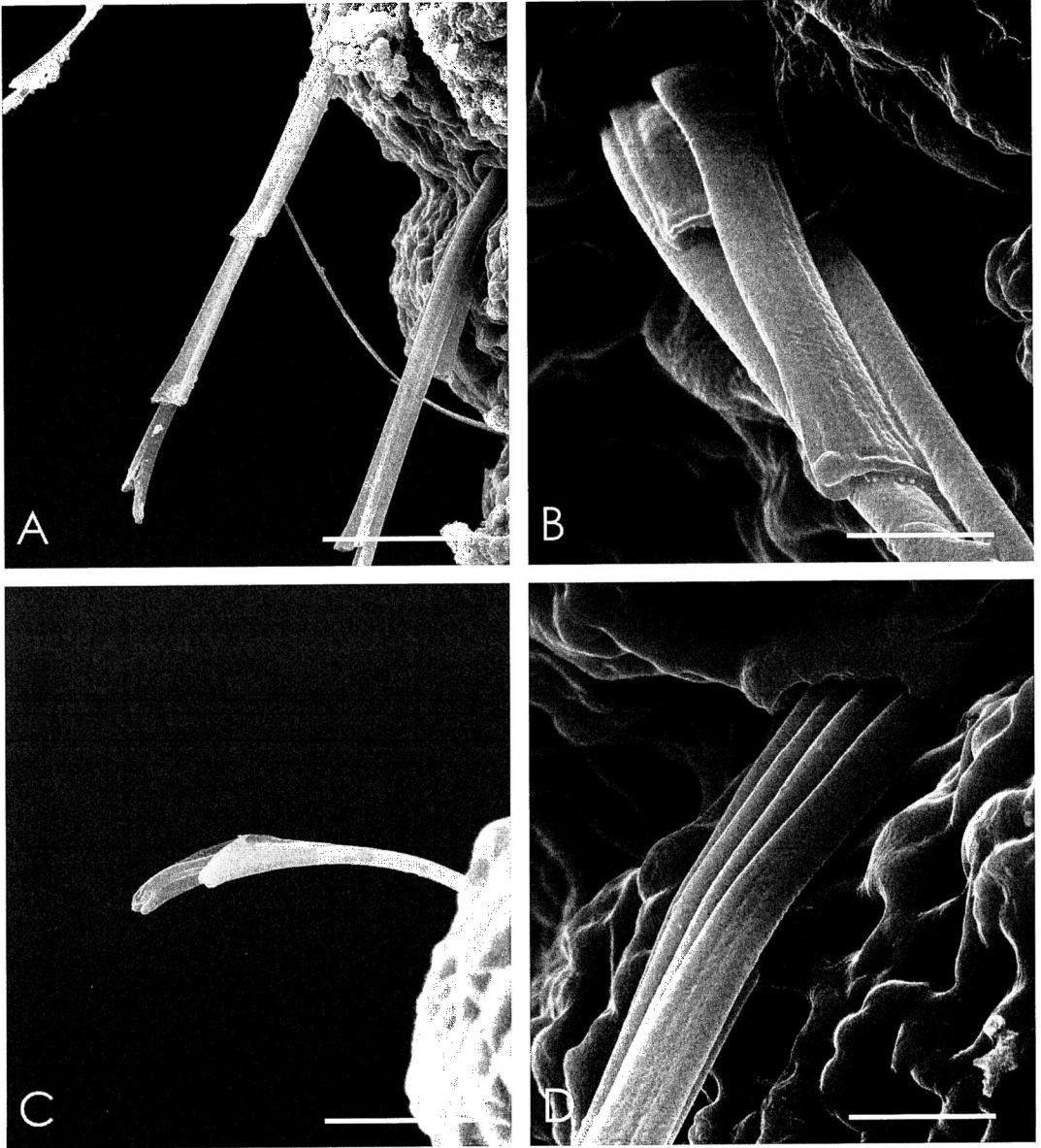


FIGURE 10. Scanning electron micrographs of *Saccocirrus waianaensis*. A, Chaetae; B, fascicle with four apparent chaetae; C, forked and longest chaetae; D, four chaetae emerging at the base of a fascicle. Scales: A, 17.6 μm ; B, 4.3 μm ; C, 8.6 μm ; D, 5.0 μm .

O'ahu also lacked eyes, so it is probable that *S. waianaensis* lacks eyes. These recently found specimens were in a sand pocket among coral rubble and live coral colonies

(*Porites lobata* Dana) at a depth of 2.58 m near the end of Makai pier. One specimen was collected off Hilo Bay, Hawai'i, in coarse sand at a depth of 5.6 m.

ETYMOLOGY: *Saccocirrus waianaensis* is named for the type locality, Wai'anae, a coastal town in leeward O'ahu.

DISCUSSION

Saccocirrids are interstitial polychaetes, formerly considered primitive "Archiannelida" due to their small size and simple body plan. They are highly modified from the typical biramous parapodium-bearing polychaete, having cylindrical uniramous parapodia without acicula, three or four kinds of chaetae that are often forked, fluid-filled palps with ampullae, and reproductive segments with ova and sperm-filled spermathecae. Viviparity has been described in some saccocirrids (Silberbauer 1969). These small polychaetes with adhesive glands on papillae or ventral epithelium are well adapted to interstitial and high-energy habitats (Westheide 1990). Chaetae are present in Saccocirridae, Nerillidae, and some Protodriloidae and are absent from Polygordiidae, Protodrilidae, and Dinophilidae. Chaetation of saccocirrids is very different from that of the other two families. Nerillids have many more chaetae per fascicle than saccocirrids, and Protodriloidae lack parapodia but have sigmoid chaetae or segmental adhesive glands. Saccocirrids are closest to protodrilids (lack parapodia and chaetae) and protodriloids (with chaetae).

Protodrilidae and Saccocirridae were classified in the order Protodrilida by Pettibone (1982) and in Canalpalpata (united by having hollow palps) by Rouse and Fauchald (1997). Saccocirridae contains a single genus, *Saccocirrus* Bobretsky, 1872, and are known from sand habitats around the world (Brown 1981).

The 18 known species are placed in two groups. One group includes those with bilaterally situated gonads; the other group has, with one exception (*Saccocirrus burchelli* Silberbauer), unilateral gonads. Those with bilateral gonads are usually without a muscular pharyngeal pad (except for *S. cirratus*) and lack cilia in the peristomial and ventral grooves. Those with unilateral gonads usually have a muscular pharyngeal pad; peristomial and ventral groove cilia; and long, furcate

chaetae (Brown 1981, Sasaki 1981). Pygidial palpcilids were seen in specimens of *S. oahuensis* (Figure 5G, G¹).

The three species of saccocirrids are from very different habitats. *Saccocirrus alanbongi* specimens are found in sand of shallow, high-energy, and frequently trampled or disturbed habitats. *Saccocirrus oahuensis* is found in coarse-grain sands from subtidal depths in Māhala Bay, Mōkapu, and Honolulu Harbor, and *S. waianaensis* is found at 30- to 33 m depths off Wai'anae, 2.58 m off Waimānalo and 5.6 m off Hilo. Saccocirrids adapt to high water motion conditions from surf and tidal change. Their adhesive glands attach to sand grains, which keep them on the bottom. Sand grains attached to anal papillae and adhesive glands provide a "weight belt" to reduce buoyancy and increase sinking following resuspension due to wave backwash. The Hanauma site is a public beach and Marine Life Conservation District that has 600–1200 bathers entering and leaving the water per day and trampling through the saccocirrid sand habitat. The water adjacent to the beach is an area frequented by mixed schools of adult and juvenile (less than 3 cm in length) *Mugil cephalus* (mullet), *Kublia sandwicensis* (flagtails, āholehole), and *Mulloidichthys vanicolensis* (goatfish). Some of these fish may pick small invertebrates from the sand and suspended in the water column. The fish avoid potential predators by patrolling the beach margin and benefit from sand disturbance by bathers. Saccocirrids may be components of their diet, but this assumption is hypothetical without gut content studies. Saccocirrids have been described as carnivorous, with fish and copepods in the gut (Jouin 1971). Similarly, *S. alanbongi* guts have been observed to contain fragmented material (most likely bacteria, algal cells, and diatoms), a copepod, and foraminiferans. The muscular pharynx may function here, and for others in this group, as a way to crush large particles. One *S. alanbongi* specimen (mounted on a glass slide with a coverslip) had everted the anterior gut contents, and shards of diatom frustules and dark green material were seen. Preserved specimens of *S. oahuensis* had guts containing

foraminiferans that are readily seen with light microscopy (Figure 5E). The benthic invertebrates at 0.5-m depth in the trampled zone at Hanauma retained on the 0.5-mm sieve were saccocirrids and nematodes only. The benthos retained on the 0.25-mm sieve included saccocirrids, harpacticoid copepods, mites, ostracods, acoels, nematodes, and *Nerilla antennata*. Such low diversity at the 0.5-m site suggests a highly perturbed environment close to shore. The Keyhole site at Hanauma (3.5 m deep) had more diverse benthic communities retained on 0.5-mm and 0.25-mm sieves, with gammarid amphipods and nematodes being most abundant. In the 0.25-mm sieve fraction syllids, dorvilleids, spionids, and kinorhynchs were more abundant than saccocirrids, *Protodrilus* sp., *Nerilla antennata*, and *Mesonerilla fagei*. Saccocirrid densities were 12,760 individuals per square meter at 0.5-m depth and up to 9020 individuals per square meter at 3.5-m depth.

The Fort Kamehameha reef community was much more diverse and richer in invertebrate fauna when sampled in 1977. Water motion averaged 9.8 cm/sec at the sampling site on the seaward reef margin. Saccocirrid density was 9660 individuals per square meter, and none was found at the other reef flat sites. The greatest percentage of coarse grains were here, and saccocirrids were the most abundant polychaetes collected in sand (Bailey-Brock 1979). Despite being accessed from military bases, the reef is used by recreational fishers and commercial seaweed collectors. There is some foot traffic at low tides, but this is minimal compared with the daily activity at Hanauma Bay.

The saccocirrids known to date are as follows: species without the pharyngeal pad and with bilateral position of the gonads (*S. papillocerus* Bobretzky, 1872; *S. major* Pierantoni, 1907; *S. minor* Aiyar & Alikunhi, 1944; *S. orientalis* Alikunhi, 1946; *S. pussicus* Marcus, 1948; *S. parvus* Gerlach, 1953; *S. archiboldi* Kirsteuer, 1967; *S. heterochaetus* Jouin, 1975); one with a pharyngeal pad (*S. cirratus* Aiyar & Alikunhi, 1944); and those with unilateral position of the gonads and a pharyngeal pad (*S. gabriellae* Marcus, 1946; *S. krusadensis* Alikunhi, 1948; *S. eroticus* Gray, 1969; *S. burchelli*

Silberbauer, 1969; *S. labilis* Yamanishi, 1973; *S. sonomacrus* Martin, 1977; *S. uchidai* Sasaki, 1981; *S. jouinae* Brown, 1981; *S. tridentiger* Brown, 1981).

CONCLUSIONS

The three new species of saccocirrids add to the interstitial fauna of Hawaiian sand habitats. Two belong to the subgroup having bilateral gonads and the third to the group with a muscular pharynx and unilateral gonads. *Saccocirrus alanbongi* occupies shallow subtidal and intertidal habitats with high water motion. *Saccocirrus oahuensis* and *S. waianaensis* are from deeper sand habitats below the high-energy habitats of reef flats and beaches. All three species are smaller than most other saccocirrids. Three species from Australia measure 20 mm long, from India *S. minor* 10–15 mm and *S. cirratus* 40–45 mm, and *S. uchidai* from Japan is 20 mm long (Sasaki 1981). In general, Hawaiian polychaetes are smaller than their close relatives from continental margins and cooler latitudes, but the differences here cannot be attributed to immature or subadult condition of specimens because reproductive characters were observed in all three species. The three new species are distinguished from others based on size, chaetal characters, and number of segments.

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