STUDIES ON THE TETRACLITIDAE (CIRRIPEDIA: THORACICA) A NEW TETRACLITELLAN FROM INDIA

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ABSTRACT — *Tetraclitella* contains eight species, including *T. karandei* n. sp. from Mad'h Island, India, all of which are restricted largely to the Indo-West Pacific faunal province. Two groups may be recognized in this genus on the basis of opercular morphology. One species in each of these groups has radii that are elevated well above the surface of the parietes. In *T. darwini* the elevated radii serve to strengthen the shell in the absence of sutural ridges and denticulae; in *T. karandei* they probably create water turbulence and thus enhance the fishing capabilities of the cirral net.

Tetraclitella comprises eight, relatively small, patelliform, balanomorph barnacles that occupy habitats low in the intertidal zone. They are confined largely to the Indo-West Pacific faunal province, contrary to the statement by Utinomi (1970: 349) that they are "mostly circumtropical." All of the species occur predominantly on continental islands but there are a few scattered mainland records. Exceptions to this distribution pattern are *T. purpurascens*, which ranges from Australia to India, and *T. divisa* which is the only species that occurs circumtropically (Ross, 1968: 14).

The barnacle fauna of India and adjacent areas is relatively well known through the work of Annandale, Nilsson-Cantell, Karande (1966) and several contemporary Indian workers. Therefore, it is surprising to note the presence of a new tetraclitellan from Mad'h Island on the Bombay coast of India (Fig. 1). This new species is similar in many ways to the widely occurring *T. purpurascens*, and records for that species should be reevaluated in the light of the present discovery.

Dr. A. A. Karande, who collected the specimens reported on here, informed me that it occurs on the under surface of rocks, low in the intertidal zone, where it normally remains moist during periods of low tide. The shells commonly are covered with a dense mat of brownish-green, finely particulate, organic matter. The associated animals include the ubiquitous *Planaxis sulcatus* Born and a species of *Acmaea*. The ecological conditions under which this species lives and the few animals with which it is associated do not differ appreciably from those of other species of *Tetraclitella*.

Family Tetraclitidae Gruvel, 1903

Genus *Tetraclitella* Hiro, 1939

Definition.—Shell generally less than 20 mm in rostro-carinal diameter, patelliform, ribbed; compartments discrete; parietes with 2 or more rows of tubes; radii broad, flush with or raised above parietal surface, summits horizontal, tubiferous, lacking teeth or denticles on articular surface; alae non-tubiferous; basis membranous, calcareous peripherally or wholly calcareous; scutum transversely elongated or higher than wide, commonly ornamented externally, lacking crests for depresser muscles; mandible with 5 teeth and spine-like lower angle; maxilla I with 6-8 major spines below subapical notch.

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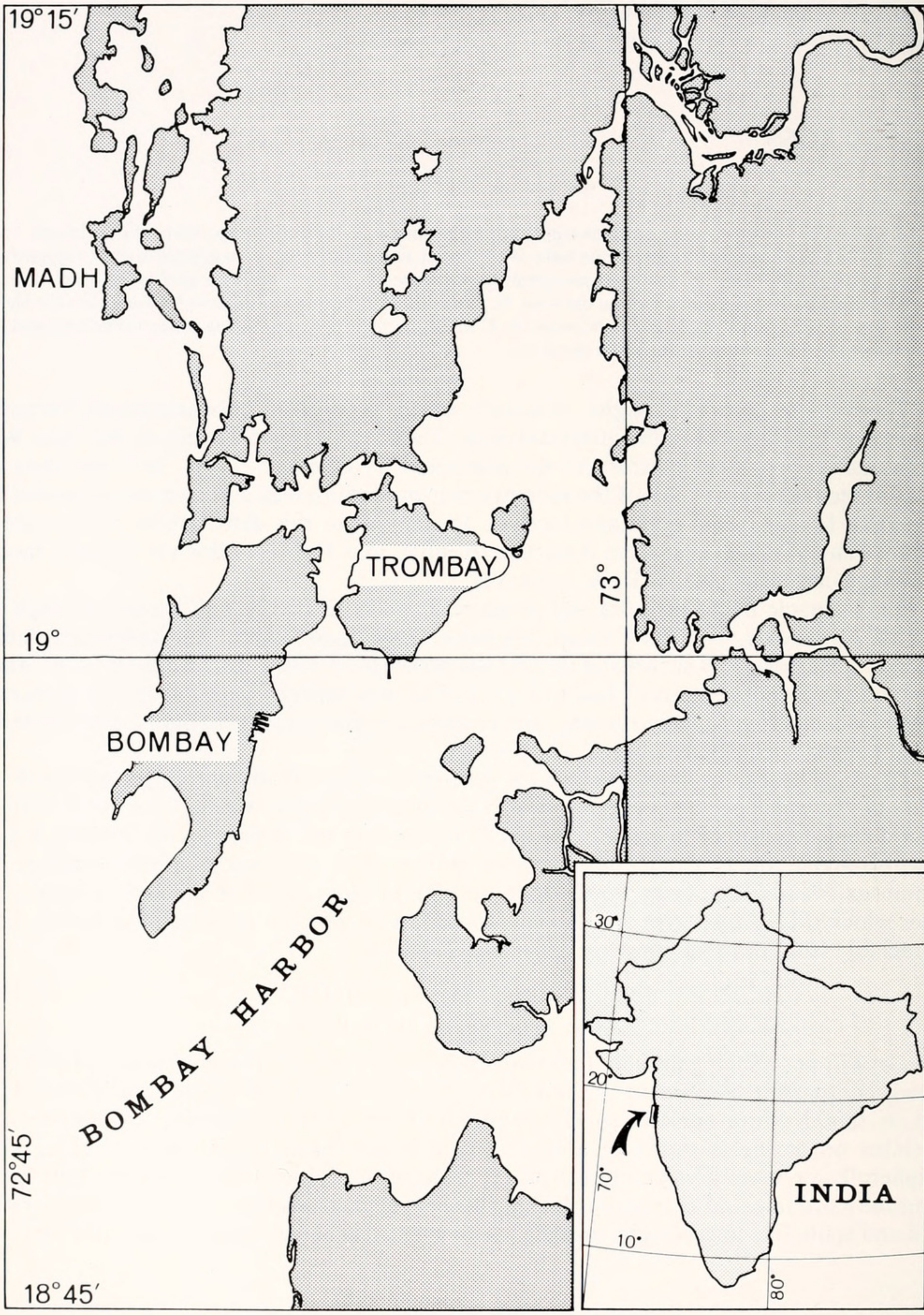

Figure 1. Map showing position of Mad'h Island relative to other islands along the Bombay coast of India.

Type species.—*Lepas purpurascens* Wood (1815: 55), Recent, Australia, by original designation of Hiro (1939: 273).

Remarks.—Hiro (1939: 273) established *Tetraclitella* as a subgenus of *Tetraclita*. Recently, in reevaluating the tetraclitids I raised the subfamily to familial status (Ross, 1968: 6), and accordingly the subgenera of *Tetraclita* were raised to genera to better reflect relationships within the family (Ross, 1969: 237; Ross, 1970: 3). Utinomi (1970: 349) independently also accorded *Tetraclitella* generic rank.

Species referable to *Tetraclitella* include: *T. purpurascens* (Wood, 1815: 55), *T. costata* (Darwin, 1854: 339), *T. chinensis* (Nilsson-Cantell, 1921: 359), *T. divisa* (Nilsson-Cantell, 1921: 362), *T. darwini* (Pilsbry, 1928: 314), *T. multicostata* (Nilsson-Cantell, 1930: 2) and *T. pilsbryi* (Utinomi, 1962: 234). *Tetraclita squamosa depressa* (Kolosvary, 1941: 42) from southern Australia, *Tetraclita purpurascens darwini* (Kolosvary, 1942: 140) from Port Jackson, New South Wales, Australia, and *Tetraclita radiata wagneri* (Kolosvary, *in* Kolosvary and Wagner, 1941: 11) from Tasmania, on the basis of morphology and biogeography, are apparently conspecific with *T. purpurascens purpurascens*.

KEY TO THE SPECIES OF *TETRACLITELLA*

1. Radii elevated above surface of parietes 2
1. Radii flush with or sunken below surface of parietes 3
2. Scutum higher than wide; intermediate segments of cirrus VI with 4 pairs of setae (Japan, Formosa) . . . . . *T. darwini*
2. Scutum wider than high; intermediate segments of cirrus VI with 3 pairs of setae (India) . . . . . *T. karandei*
3. Scutum higher than wide 4
3. Scutum wider than high 5
4. Scutum with a row of small longitudinal pits; intermediate segments of cirrus VI with 4 pairs of setae; basis calcareous (Lesser Sunda Islands, Sulu and Philippine Archipelagos) . . . . . *T. costata*
4. Scutum with 5 rows of longitudinal pits; intermediate segments of cirrus VI with 3 pairs of setae; basis membranous (Japan) . . . . . *T. pilsbryi*
5. Tergal spur essentially confluent with scutal margin 6
5. Tergal spur well separated from scutal margin (intermediate segments of cirrus VI with 3 pairs of setae; circumtropical) . . . . . *T. divisa*
6. Parietal plates without hollows 7
6. Parietal plates pierced by hollows (intermediate segments or cirrus VI with 4, rarely 3 pairs of setae; southern China, Formosa, Japan) . . . . . *T. chinensis*
7. Shell with 14 or fewer primary longitudinal ribs; cuticle persistent (West Irian, New Guinea) . . . . . *T. multicostata*
7. Shell with 20 or more primary longitudinal ribs; cuticle not persistent (intermediate segments of cirrus VI with 2 pairs of setae; New Zealand, Tasmania, Australia, Malay Archipelago, India) . . *T. purpurascens*

Tetraclitella karandei n. sp.

Diagnosis.—Radii transversely ridged, the apical 3-4 ridges extending like fingers out and over adjoining plate; scutum transversely elongated, externally ornamented with prominent nodes where longitudinal ridges cross growth lines; intermediate articles of posterior cirri armed with 3 pairs of setae.

Description.—Shell white or grayish white, patelliform, ovate in outline, covered with persistent, hirsute, chitinous cuticle; parietes ornamented with prominent growth ridges, and high, primary, longitudinal ribs intercalated with lower secondary and tertiary ribs; ribs square or T-shaped in section, extending from orifice to or beyond basal edge of shell, occasionally bifurcate basally (Fig. 2a, b); orifice diamond-shaped; radii broad, horizontally ridged from base to apex, the ridges becoming progressively higher, produced and free from the surface (Fig. 2a); articular margin and finger like projections tubiferous, the apertural margins of the tubes being crenate; on the adjoining plate a narrow, longitudinal ridge occurs on parietal surface where the radius butts against the plate (Fig. 2b); alae broad, summits horizontal and crenate; sheath less than ½ height of wall, basal margin not depending; basis calcareous peripherally.

Scutum wider than high; external surface deeply sulcate (Fig. 2e); where the growth ridges are crossed by longitudinal ridges prominent nodes are formed thus rendering a scabrous appearance; articular ridge straight, about 2/3 length of tergal margin; adductor ridge low, not undercut, apically fused with articular ridge, terminating basally at basi-occludent angle; adductor muscle depression ovate, shallow, borders poorly delimited; depression for lateral depressor muscle shallow, poorly defined; depression for rostral depressor muscle lacking; apical portion of plate with weak ridges (Fig. 2d).

Tergum higher than wide; external longitudinal furrow open, broad, shallow, extending to base of spur; spur evenly rounded basally, confluent with scutul margin, width about ½ that of basal margin (Fig. 2g); articular ridge inclined; articular furrow wide and shallow; 6-7 crests for depressor muscle, low, short, inclined; apical portion of valve ridged or roughened (Fig. 2f).

Measurements of the holotype are as follows (in mm): rostro-carinal diameter 10.1; height 3.5; rostro-carinal diameter of orifice 3.6; height of scutum 1.5; width of scutum 2.1; height of tergum 1.5; width of tergum 1.0. The mean rostro-carinal diameter of five paratypes is 13.5 mm and the height is 3.8 mm.

Labrum with shallow, broad, medial depression; crest thick, heavily chitinized,armed with short, fine bristles but rarely with teeth (Fig. 3a). Palps long, broad, distal end broadly rounded; superior margin straight, basal margin convex; proximal setae on superior margin short, stout, coarsely bipectinate; distal setae on margin long, slender, finely bipinnate; basal portion of lateral surface covered with ctenae. Mandible with 5 unequally spaced teeth; teeth 2 and 3 commonly with 1-2 subsidiary cusps; tooth 4 with 3-5 subsidiary cusps; comb between tooth 5 and inferior angle containing 8-12 teeth; inferior angle commonly with 1 long, slender and 1 short, stout tooth (Fig. 4). Maxilla I with 2 long, stout and 1-2 shorter spines above sub-apical notch; 2-3 short, slender spines in notch; 6-8 stout spines medially; 8-12 short, slender spines in basal cluster (Fig. 3c). Maxilla II bilobate; setae along apical margin long; bipinnate, setae becoming progressively shorter toward the notch; setae on basal lobe coarse, bipectinate.

Posterior ramus of cirrus I about 3/5 length of anterior ramus; intermediate articles of both rami broader than high; segments of anterior ramus normal, but those of posterior ramus protuberant; distal articles of both rami clothed with finely bipinnate setae (Fig. 3g). Rami of cirrus II essentially equal in length, and slightly longer than posterior ramus of cirrus I; medial segments of both rami protuberant; distal two segments of both rami armed with bipectinate setae, proximal segments with bipinnate setae (Fig. 3h). Rami of cirrus III of equal length, and same length as rami of cirrus II; medial segments of both rami protuberant; distal 2 or 3 segments of anterior ramus and all segments of posterior ramus armed with bipectinate setae (Fig. 3i). Cirri IV-VI essentially equal in length with equal rami; 1-2 stout spines and 2-3 long, slender setae at each articulation along greater

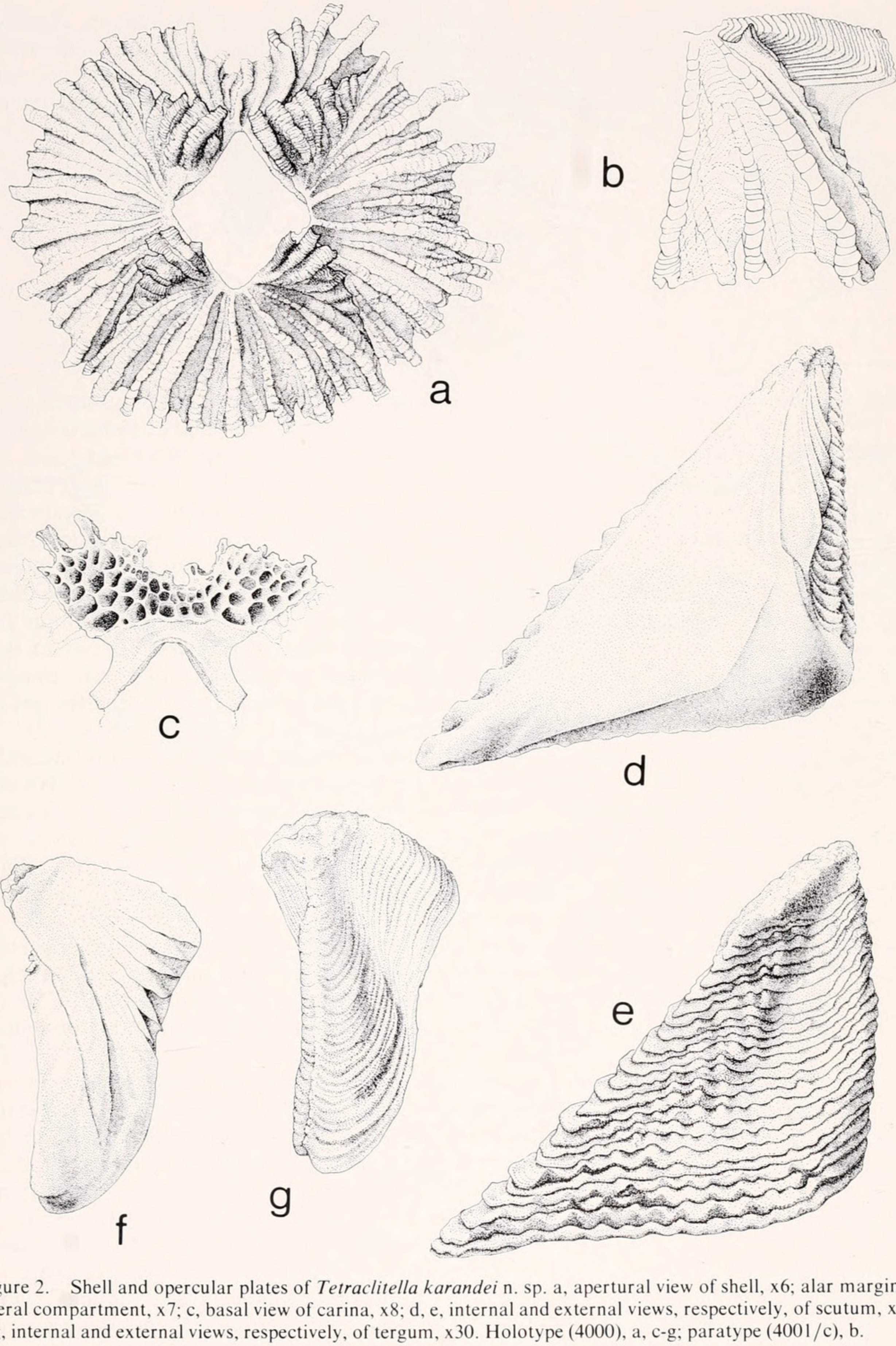

Figure 2. Shell and opercular plates of *Tetraclitella karandei* n. sp. a, apertural view of shell, x6; alar margin of lateral compartment, x7; c, basal view of carina, x8; d, e, internal and external views, respectively, of scutum, x30; f, g, internal and external views, respectively, of tergum, x30. Holotype (4000), a, c-g; paratype (4001/c), b.

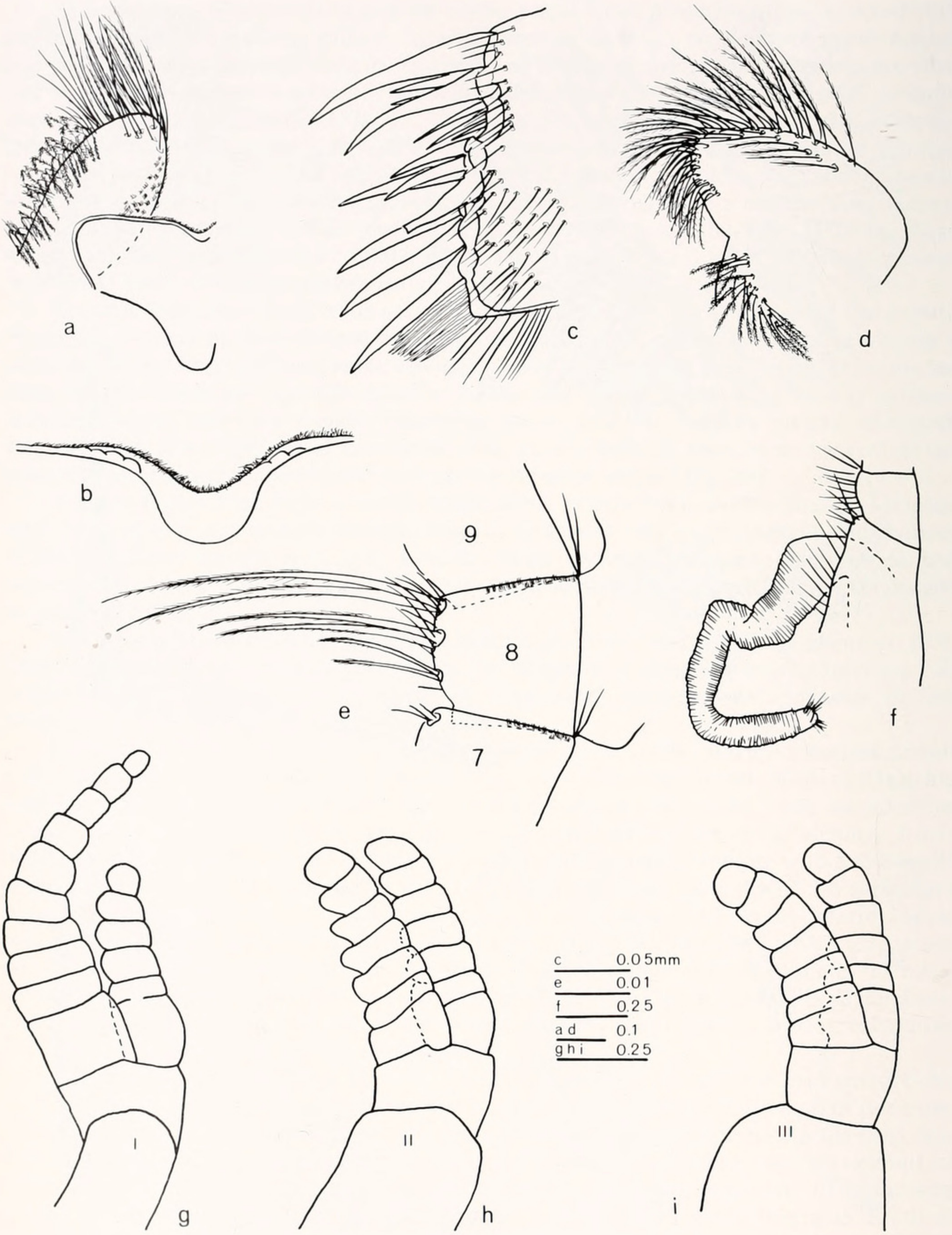

Figure 3. Trophi and cirri of *Tetraclitella karandei* n. sp. a, labrum and palp; b, enlarged view of labrum; c, maxilla I; d, maxilla II; e, intermediate segments of outer ramus of cirrus VI; f, penis; g, cirrus I; h, cirrus II; i, cirrus III. Holotype (4000), c, f; paratypes, a-b, d-e, g-i (a, d = 4001/c; b = 4001/d; e, g-i = 4001/b).

curvature of intermediate segments; 1 or 2 rows of ctenae present on lateral face of intermediate segments immediately below articulation; setation ctenopod, with 3 pairs of setae on each intermediate segment, and commonly a single proximal, short seta; at base of and between each major pair of setae there is a cluster of 3-5 short, slender setae (Fig. 3e). Cirral counts for specimens in the type lot are summarized in Table 1.

Table 1. Summary of data on cirral counts: range (R) and mean (X) value for number of segments in anterior (a) and posterior (p) rami

	I		II		III		IV		V		VI	
	a	p	a	p	a	p	a	p	a	p	a	p
N	10	10	12	12	11	11	7	7	6	6	4	4
R	10-11	6-7	7-8	6-8	6-8	6-9	11-14	11-15	14-16	15-17	15-16	15-18
X	10.6	6.3	7.3	7.1	7.1	6.2	12.8	14.0	15.0	15.2	15.5	16.7

Intromittent organ annulated throughout its length, and sparsely covered with short, slender bristles; distal extremity with 4 clusters of 11-14 setules (Fig. 3f).

Remarks.—Of the presently recognized tetraclitellans, *T. karandei* may be distinguished by its radii, which have raised digitiform processes that extend out and over the adjoining plates. The shape of the tergum in *karandei* is similar to that found in *multicostata, purpurascens* and *chinensis*, but the scutum of this species has a scabrous or nodose ornamentation externally rather than only simple growth ridges. The mandible of *karandei* appears to be more variable than any other species in the degree of development and number of subsidiary cusps on the second, third, and fourth teeth (see Fig. 4). The crest of the labrum is commonly devoid of teeth as it is in *purpurascens, costata* and *darwini*. But when teeth are developed, they appear as simple, low, rounded knobs, that are few in number. The mouth parts and appendages have not been described for *pilsbryi.*

Disposition of types.—The holotype and four paratypes are housed in the collections of the San Diego Society of Natural History, Marine Invertebrate catalogue numbers 4000 and 4001, respectively. Two paratypes are in the collections of the Zoological Survey of India, Calcutta. The remaining specimens have been retained by the author.

Type locality.—Mad'h Island, Bombay Coast, India, approximately 19°8'N., 72°47'22"E.; A. A. Karande coll. 1969; 10 specimens.

Comparative material.—I have examined specimens of the following species:

T. divisa: western side of Panto Hole Bay, east of town of Marigot, Dominica; approximately 15°32'21"N., 61°17'31"W., intertidal on *Tetraclita stalactifera* (Lamarck); E. Kirsteuer and K. Rützler coll., 1–10 May 1966 (see Ross, 1968:13).

T. chinensis: Suô (Suao), Taiwan, approximately 24°35'45"N., 121°51'10"E., " . . . on sheltered undersurface of stones in the littoral"; F. Hiro coll., 30 May 1938 (see Hiro, 1939: 277).

T. purpurascens: Eddystone Point, Tasmania, approximately 40°59'30"S., 148°20'E.; I. Bennett coll., 20 June 1964. The Nobbies, Phillip Island, Victoria, Australia, approximately 38°30'S., 145°16'E.; E. C. Pope coll., May 1949. Little Papanui, Otago Peninsula, South Island, New Zealand, approximately 45°50'S., 170°43'E.; C. Hand coll., 4 November 1959.

T. darwini: Isle Hatake-zima, Tanabe Bay, Wakayma Prefecture, Japan, approximately 33°43' N., 125°21'30" E.; F. Hiro coll., 3 April 1928.

Etymology.—The specific epithet honors Dr. Ashok A. Karande, Senior Science Officer, Naval Chemical and Metallurgical Laboratory, Bombay, India, who collected the specimens.

Figure 4. Mandibles of *Tetraclitella karandei* n. sp. and related tetraclitellans. A, E, right and left, respectively, holotype (4000); B, F, right and left, respectively, paratype 4001/b; C, G, right and left, respectively, paratype 4001/c; D, H, right and left, respectively, paratype 4001/d; I, K, right and left, respectively, paratype 4001/e; J, right, paratype, Zool. Survey India; L, after Utinomi, 1962; M, from Dominica; N, from Taiwan; O, from Tasmania; P, from Japan.

DISCUSSION

There are two groups in *Tetraclitella* based primarily on the morphology of the operculum. In the first, consisting of *costata, pilsbryi*, and *darwini*, the scutum is higher than wide and externally ornamented with one or more longitudinal rows of pits, and the tergum composes about one-half or more of the bulk of the operculum. In the balanomorphs a tall, narrow scutum generally correlates with a relatively tall shell; in these three species the shell is relatively tall. In the second group, consisting of *purpurascens, multicostata, divisa, chinensis*, and *karandei* n. sp., the scutum is transversely elongated and lacks the longitudinal rows of pits, and the tergum composes less than one-half of the bulk of the operculum. I consider the *costata* group to be the phylogenetically more primitive on the basis of the opercular valves, which are characteristic of geologically early balanomorphs.

One species in each of the above groups develops radii that are elevated well above the surface of the parietes (*darwini* and *karandei*). Radii develop essentially normal to the parietes and function to enlarge and strengthen the shell. Similar functions are served by the alae (Darwin, 1954: 36, 45-48), which are always non-tubiferous, contrary to the statements of Pilsbry (1928: 316), and Hiro (1939: 273). The sutural surface of the radius abuts against and fits into a furrow in the opposed compartment, the outer edge of which may be raised to form a lip, as in *darwini* and *karandei*. In *darwini* this lip, an extension of the parietes, is tubiferous. I infer that the elevated radii in *darwini* serve primarily as a means of developing a larger sutural surface for strengthening the shell, especially in the absence of sutural ridges and denticulae. Attempts to manually separate the plates in this species are rarely if ever successful. Conversely, the plates in *karandei* are easily separated from one another. However, in *karandei* the development of a prominent lip on the adjoining compartments (Fig. 2b) may serve to strengthen the articulation of the plates.

Because the parietal plates of *karandei* are weakly articulated, and because *karandei* occupies a protected habitat low in the intertidal zone, it is reasonable to assume that the finger-like projections on the exposed radial surfaces serve a different function than the raised radii of *darwini*. I believe that these projections function primarily to scatter the initial energy of the incident currents into numerous smaller components. This would create turbulence or change the water flow pattern over the shell, and consequently enhance the fishing capabilities of the cirral net.

The mode of growth of the shell in *T. chinensis* sets it apart from all other tetraclitellans. In the adult or large specimens the compartments are pierced by hollows, one in each of the laterals and two in both the rostrum and the carina. Hiro (1939: 274) considered them to be parietal tubes formed by the corrosion of the parietal wall, but it is evident from the young stages that initially these hollows are external to the parietes, and consequently they cannot be parietal tubes. The hollows result from the initial development of distally flaring extensions from the shell, the lateral tips of which subsequently meet and fuse in a manner somewhat analogous to the fusion of the terminally flanged radial buttresses in whale barnacles. I believe that this method of shell growth enables *chinensis* to rapidly develop a broad base of attachment in a high energy environment. Support for this inference comes from the fact that in the few adult specimens I have seen the shell is essentially circular in outline, lacks well preserved longitudinal ribs, and the peritreme is eroded. Alternatively, this method of shell growth may be a means to prevent overcrowding, but observations to support this suggestion are lacking.

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