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Towards understanding a confusing and widespread species: an anatomical study of *Acanthopleura gemmata* (Polyplacophora, Chitonidae) from Thailand

Jaime A. Jardim[1,*], Sergio M. Almeida[2] & Luiz R. L. Simone[1]

[1] Museu de Zoologia da Universidade de São Paulo, São Paulo, SP, Brazil.
[2] Centro de Ciências Biológicas e Saúde, Universidade Católica de Pernambuco, Recife, PE, Brazil.
*Corresponding author: jardim.jaime@gmail.com

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Abstract: *Acanthopleura gemmata* has been interpreted as a complex of species. Samples identified as *A. gemmata* were found on the coast of Thailand. The morphology and anatomy of this population are herein described. Amongst several interesting characters, the most important are the holobranchial and adanal ctenidia, a very delicate kidney restricted to the posterior half of the animal, and a simple esophagus. The odontophore, with a single pair of cartilaginous projections, has a peculiar musculature.

Key-Words: Acanthopleurinae, chiton, Gulf of Thailand, morphology.

INTRODUCTION

The genus *Acanthopleura* Guilding (1829) (type species *Chiton spinosus* Bruguière, 1792; Gray 1847) includes medium to large individuals. Their valves are usually eroded, and the girdle is dorsally covered by unarticulated calcareous spines with variable length and width. The genus comprises seven species and is widely spread around the globe (Kaas *et al*. 2006).

Acanthopleura gemmata (Blainville, 1825) is an intertidal to shallow subtidal species (0–5 m) found in the Southeast Indian Ocean, from the Andaman Islands to Eastern Tonga. Some authors have also reported records from the Marquesas Islands, off the Northern Australian coast, and the northern Philippines (Kaas *et al*. 2006). The type is probably lost and a neotype was designated by Ashby (1928). The type locality is Dunk Island, Queensland, Australia.

The goal of the present study is to provide a detailed description of the external and internal morphology of *Acanthopleura gemmata* based on well-preserved samples from Thailand (Figure 1), taking the opportunity to report a new occurrence off the Thai coast.

MATERIAL AND METHODS

Samples studied herein consisted of four specimens preserved in ethanol and deposited in the malacological collection of the Museu de Zoologia da Universidade de São Paulo (MZSP, Brazil). Specimens were immersed in ethanol and dissected via standard techniques under a stereomicroscope (Jardim & Simone 2010). All drawings were made with a camera lucida. Photographs were obtained under a Zeiss Discovery V12 stereo microscope coupled with a Zeiss AxioCam MRc5 and processed with Zeiss AxioVision SE64 Rel 4.8 imaging software. Hard structures such as the radula and girdle were coated with gold alloy and examined and photographed under SEM at the MZSP SEM Laboratory.

The main systems described, due to the absence of more detailed information, were compared with literature about anatomical aspects of chitons: Sampson (1894) for *Chaetopleura apiculata*, *Rhyssoplax ol-*

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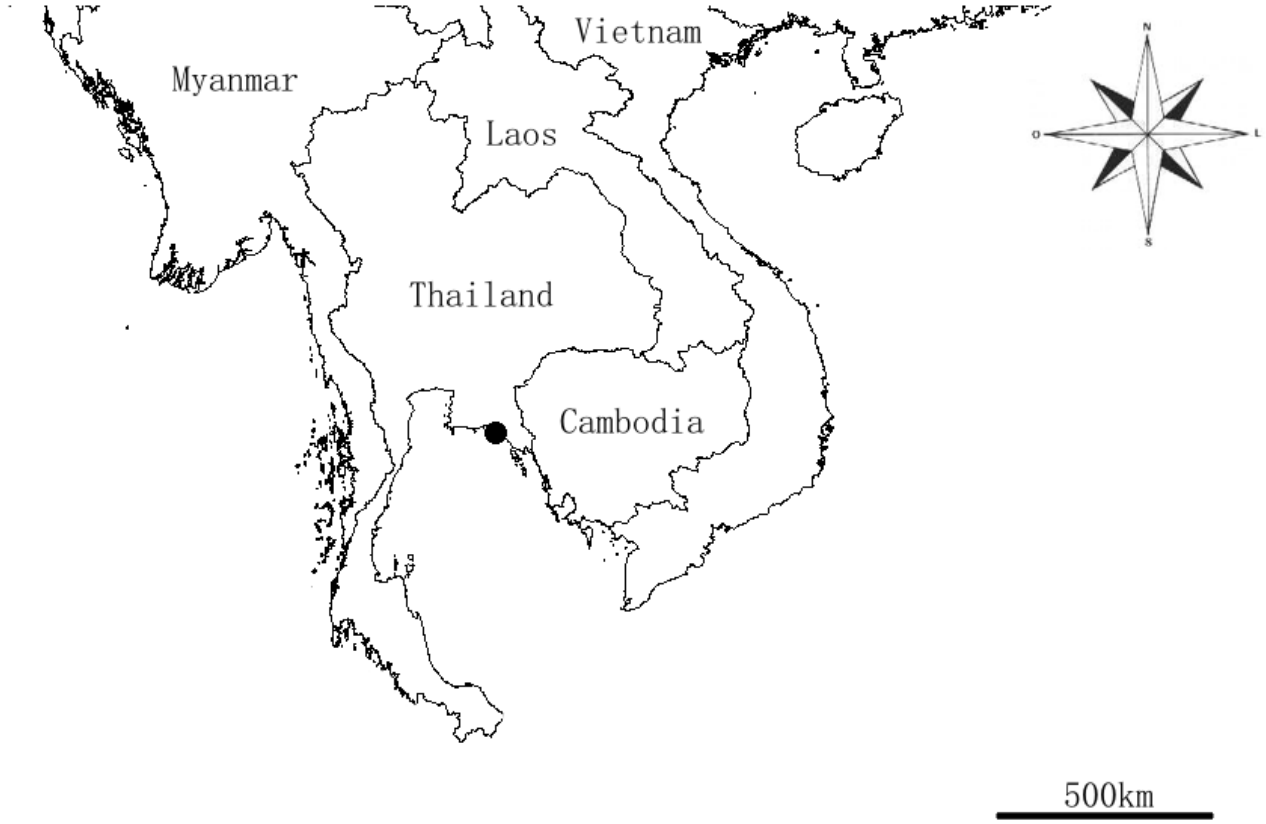

Figure 1. Distribution map with the locations of the examined material (modified from Google Maps).

ivacea, *Chiton viridis*, *Sypharochiton pelliserpentis*, *Acanthopleura granulata* and *Lepidopleurus cajetanus*; Yonge (1939) for *Lepidochitona cinerea*, *Tonicella marmorea*, *Acanthochitona crinita* and *Leptochiton asellus*; Fretter (1936) for *Lepidochitona cinerea*; Kaas & van Belle (1985) for *L. cinerea*, *Callochiton sptemvalvis*, *Acanthochitona fascicularis*, *Tonicia* sp., *Acanthochitona* sp. and *Callochiton* sp.; and Wingstrand (1985) for *Acanthopleura spiniger* and *Leptochiton asellus*.

Abbreviations: aa, aorta; af, afferent ctenidia vessel; an, anus; sg salivary gland, auricle; bm, buccal mass; cm, preoral muscle; cp, odontophore cartilage projection; df, dorsal fold; dg, digestive gland; dw, dorsal wall of bm; ec, esophageal glandular complex; ef, efferent ctenidia vessel; es, esophagus; gf, lateral longitudinal muscle; gh, ctenidia rod; gi, ctenidia; gm, ctenidia muscle; go, gonad; gp; gonopore; gr, girdle; id, insertion of ml in anterior region of valve; in, intestine; ki, kidney; m1, buccal dilator muscle; m1d, dorsal dilator buccal muscle; m1v, ventral dilator buccal muscle; m2, radular muscle; m4, retractor radular muscle; m4v, ventral retractor muscle; m4p, posterior retractor muscle; m6, horizontal muscle; m7, Y shaped muscle; m11, ventral long muscle; ma, or oblique muscle; mb, anterior oblique muscle; mc, buccal sphincter muscle; ml, longitudinal muscle; mm, median valve; mo, mouth; mt, transverse muscle; mj, jugal muscle; ne, nephridiopore; oc, odontophore cartilage; od, odontophore; ot, outer sphincter pc, pericardium; psg, posterior salivary gland; py, pallial cavity; ra, radula; rn, radular nucleus; rs, radular sac; rt, rectum; sc, subradular cartilage; sg, anterior salivary gland; sn, snout; st, stomach; ve, ventricle. SAMA, South Australian Museum (Adelaide, Australia).

SYSTEMATICS

Family Chitonidae

Acanthopleura gemmata (Blainville, 1825)
(Figures 2–39)

Synonymy see Kaas *et al*. (2006).

Material examined: Australia, Queensland: Dunk Island, SAMA D12459, coll. J. Shirley (designated by Ashby, 1928 as neotype of *Acanthopleura gemmata queenslandica* Ashby, 1922); Australia, Western Australia, North of Shark Bay, Mauds landing, SAMA 19775, coll. T. Curton (holotype of *Acanthopleura gemmata maudensis* Ashby, 1928); Thailand, Chanthaburi Province: Kung Kraben Bay, 12°31'04"N 101°56'58"E, MZSP 54475, 4 spm (22.VII.2005); Africa, Djibouti, MZSP 99934, 1 spm, (III.2011), coll. J. Coltro-Junior.

Type locality: Dunk Island, Queensland, Australia, 17°56'S 146°06'E.

Distribution: From New Caledonia (Heros *et al*. 2007); Persian Gulf, Red Sea, Gulf of Aden, Indian Ocean, Andaman Sea, Gulf of Thailand, Celebes Sea, Java Sea, Banda Sea, Timor Sea, Arafura Sea, Bismarck Sea, Solomon Sea, Coral Sea (Kaas *et al*. 2006); Japan, Taiwan, Philippines and Western Pacific (Higo *et al*. 1999); Singapore (Tan & Woo 2010); Samoa (Ministry of Natural Resources and Environmental, Conservation International Pacific Island Programme). Thailand, Chanthaburi Province, Kung Kraben Bay (new record).

Diagnosis: Dorsal surface of girdle bearing numerous and thick spines, apices rounded, insertion small and rounded; ventral surface bearing concave scales. Ctenidia holobranchial, adanal. Valve i (head valve) semicircular; valves ii-vii mostly eroded, with slightly elevated lateral area, rounded apophyses, inconspicuous apices (due to erosion) and inconspicuous diagonal ridge; valves ii–viii with insertion plate similar to that of valve i; valves ii-vii slightly elevated, diagonal ridge well-marked, jugal and pleural areas indistinguishable; valve viii rounded, mucro anterior, diagonal ridge conspicuous, antemucronal slope straight, postmucronal slope slightly concave to straight, lacking insertion plate (replaced by callus). Stomach wide and simple, intestine elongated and narrow. Kidneys elongated, narrow and thin.

Description: Shell: (Figures 10–18) covering about 3/4 of dorsal surface; color ranging from brown in central area, to dark brown in lateral areas; sculpture barely distinguishable due to erosion, except for growth lines; valves laterally elongated; inner surface reddish brown, glossy. Valve i oval (Figures 10–12) covering about 1/5 of dorsal surface; eaves solid; insertion plate long (Figures 11, 12, 15, 18), covering about 1/3 of valve surface, bearing parallel horizontal fissures; presenting seven **ma** scars, close to anterior edge (Figures 11, 27). Valve iii (Figures 13–15) covering about 2/3 of dorsal surface; slightly convex anteriorly; apices inconspicuous; diagonal ridge inconspicuous (Figure 13); apophyses occupying about 1/4 of valve length (Figure 15), rounded and smooth; Jugal sinus narrow, occupying about 1/10 of valve surface (Figures 13, 14); presenting four different muscles scars on ventral region (Figure 14); muscle radulae longus (**m2**) scar restricted to valve ii, rounded, relatively deep, occupying about 1/10 of inner valve surface; **mr** scar elongated, deep, hourglass shaped, horizontally arranged, occupying about 1/10 of inner surface area (Figure 14); **ml** scar composed of parallel bundles, originated in valve ii, rounded, less deep, with insertion in all valves (ii–vii), each scar occupying about 1/10 of inner surface of valves (Figure 14); **ma** scar oval, close to anterior portion of apophyses, occupying about 1/10 (Figure 14); scar of **gf** deep, occupying about 1/10 inner valve surface (Figure 14). Valve viii (Figures 16–18) covering about 1/3 of dorsal surface, antemucronal slope straight (Figures 16, 18); mucro slightly anterior (Figures 16, 18); diagonal ridge visible (Figures 16, 18); postmucronal slope angulated (Figures 16, 18); insertion plate modified in callus; apophyses square, occupying about 1/10 of valve surface; **ml** scar occupying about 1/10 (Figure 17); scars of **gf** rounded, occupying about 1/10 of inner valve surface (Figure 17).

Girdle: (Figures 2, 3, 5–9, 26, 27: gr) Occupying about 1/4 of dorsal surface, color cream. Spines cylindrical, with variable length, densely covering entire dorsal surface; distribution homogeneous; spine color dark brown with white spot at distal end; base narrower than distal region; width about 1/10 of height. Ventral scales rectangular, smooth, distal end slightly concave.

Mantle cavity: (Figures 26, 31–32: py) About 42–50 ctenidial filaments present on both sides, extending from labial palp to anal region; first ctenidial filament 1/5 high than last; ctenidia holobranchial and adanal

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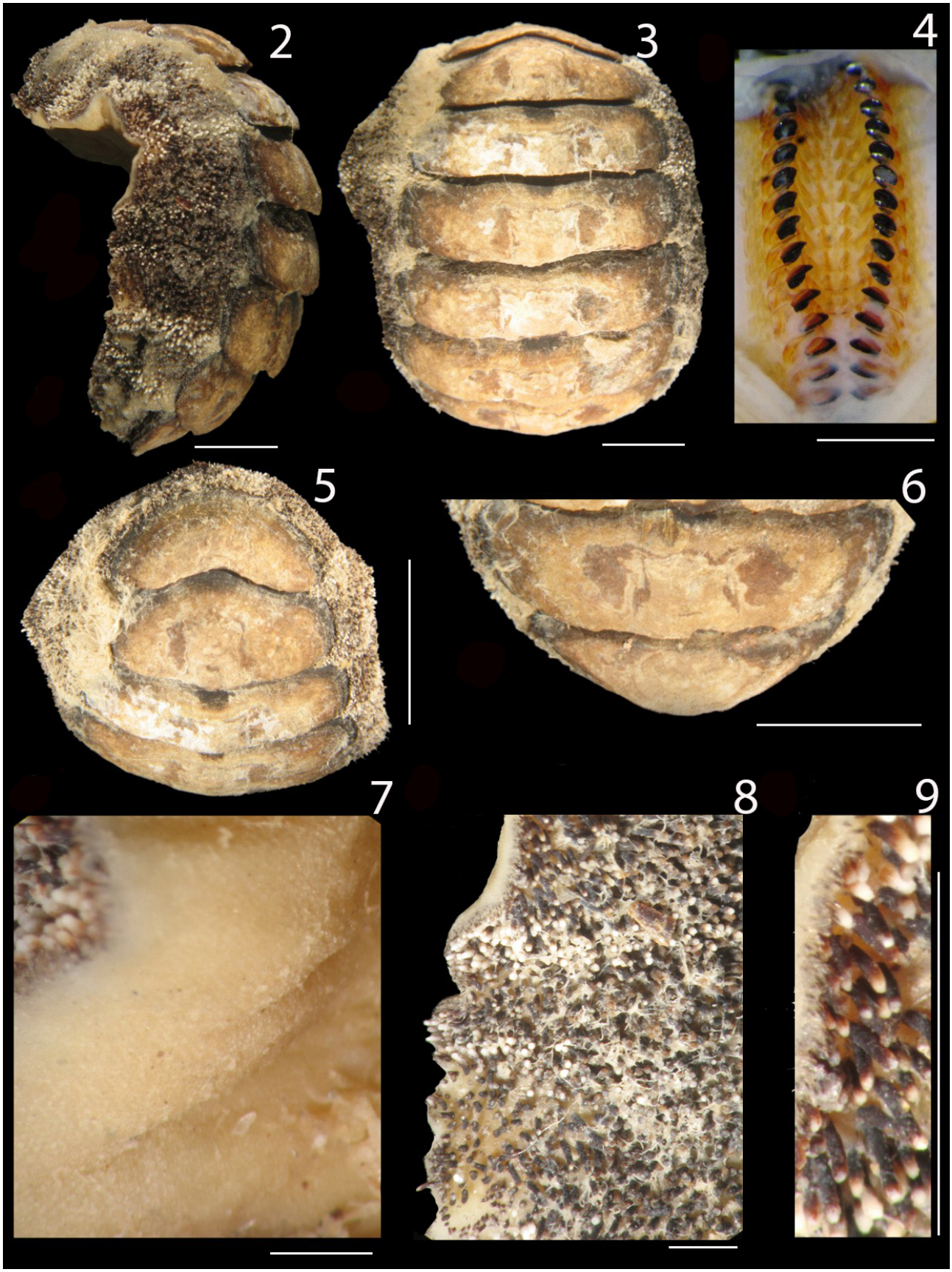


Figures 2-9. *Acanthopleura gemmata* shell. **2**, whole specimen MZSP 54475, left lateral view, scale = 5 mm; **3**, same, dorsal view, scale = 5 mm; **4**, portion of radula exposed into buccal cavity, as in situ, scale = 1 mm; **5**, whole specimen, anterior view; scale = 5 mm; **6**, detail of posterior region, scale = 5 mm; **7**, girdle, ventral view, detail of its middle region of right side, scale = 1 mm; **8**, same, dorsal view, scale = 1 mm; **9**, same, detail of edge, scale = 1 mm.

(Figures 26, 28, 29, 32: gi); ctenidial muscles arranged in two bundles, extending from base to apices; afferent vessel larger than efferent vessel about two times; ctenidial rod elongated, hourglass shaped (Figures 27, 28: gm, af, gh). Gonopore and nephridiopore opening located posteriorly (Figure 31: gp, ne).

Main muscle system: (Figure 27) preoral muscle composed of seven independent bundles, straight and narrow; originating on inner surface of valve i and extending to foot muscle; occupying about 1/10 of body surface (Figure 27: cm). Pair of straight muscles composed of long and flattened parallel bundles, originating at valves ii-viii, located between **ma** and **m2** in valve ii; anterior region separated from median line, joining posteriorly in an unique bundle, producing a reinforcement in anterior portion of each valve, occupying about 1/10 of body surface (Figure 27: ml). Six pairs of oblique muscles strong, similar-sized (slightly broader in middle valves), shape triangular and flattened, occupying about 1/10 of valve surface, originating in middle region of lateral portion of valves ii-vii, inserting immediately in posterior valve in relation to origin of the muscle; origin four times as wide as insertion; insertion close to those of **ml**; occupying about 1/10 body surface (Figure 27: ma). A simple pair of anterior oblique muscles, triangular and flattened, originating in ventral wall of haemocoel in valve ii, inserting immediately in front of ma on anterior third of valve ii; origin twice wider than insertion; insertion in ventral wall of haemocoel (Figure 27: mb) Transverse muscle composed of seven bundles, hourglass shaped; median portion five times narrower than lateral portion; connecting both sides of gf, as well as foot, occupying about 1/3 of animal dorsal surface and about 2/3 of inner surface of valve (Figure 27: mr). Ctenidia muscles composed of two bundles, located close to afferent (af) and efferent (ef) vessels; bundle near efferent vessel twice as wide as the one close to afferent vessel; connecting gf to ctenidia apices, occupying about 1/10 of body surface (Figures 27–29: gm).

Labial palp and foot: Labial palp (Figure 26: sn) broad, elliptical, occupying about 1/10 of ventral surface of body; mouth rounded. Foot straight, covered by mantle cavity and occupying about 2/3 of ventral surface of body.

Haemocoel and visceral mass: Buccal mass (Figure 26) restricted to anterior portion, occupying about 1/10 of haemocoel volume. Esophageal complex (Figure 26, 30: es) with chambers, connected to anterior portion of intestine, occupying about 1/10 (Figures 26, 30: es, in) of total visceral mass volume. Intestine extremely long, immersed in digestive gland, occupying about 2/5 of visceral mass volume; posterior portion presenting dorsal surface of rectum touching the ventral surface of pericardium, extending along surface of pericardium, connecting to anus in posterior portion of pericardium (Figures 26, 30: in, an). Heart located in pericardial chamber, occupying posterior portion of valve vii and entire valve viii (Figures 26, 32: pc, ve, au); composed of ventricle and two lateral auricles. Gonad cream colored, elongated, extending from valves ii–vii, occupying 1/5 of visceral mass volume; connected to posterolateral wall of gonoduct. Gonopore, located between ctenidial filaments (Figures 26, 31, 32: gi).

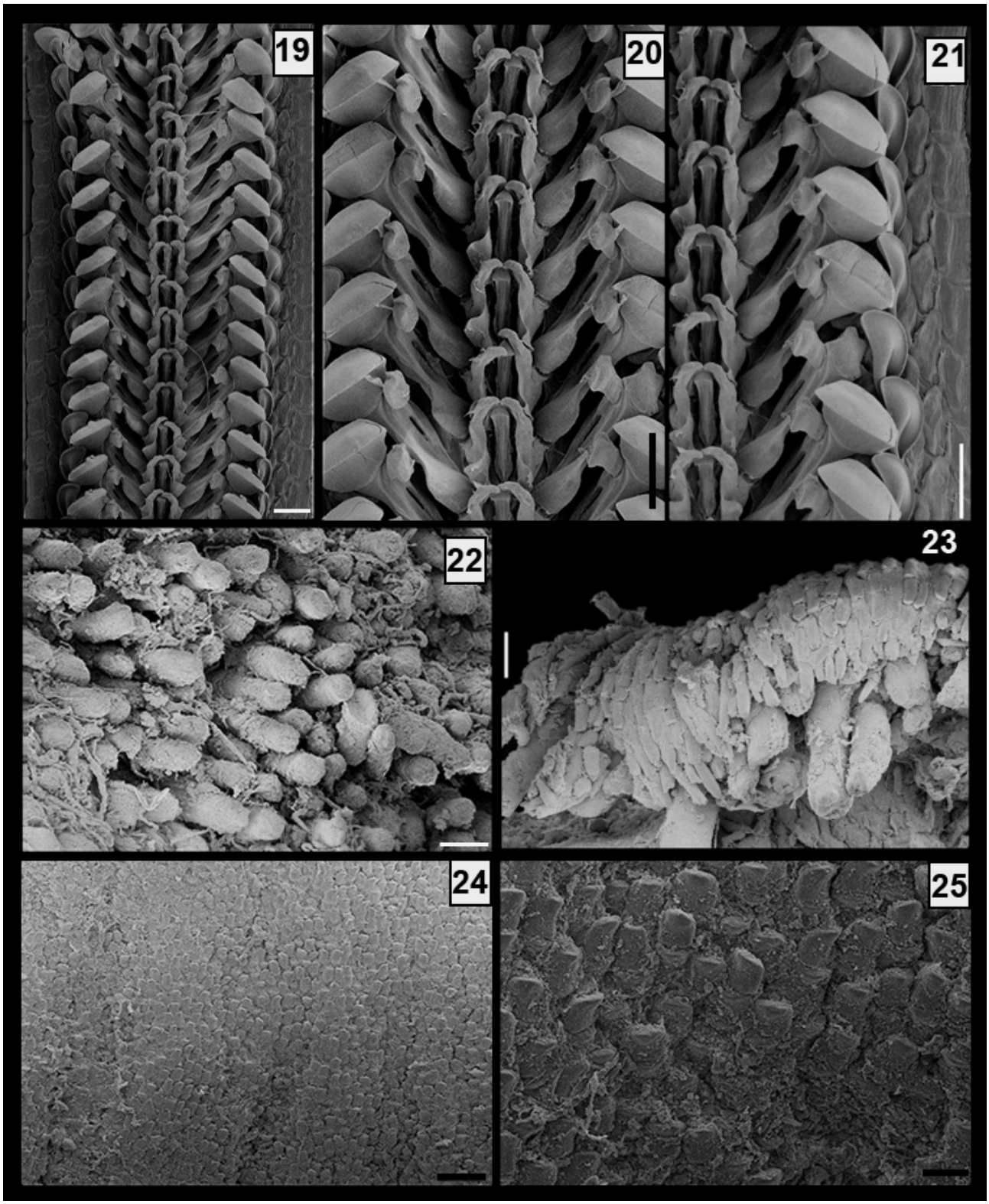
Excretory system: (Figure 32) Pair of kidneys long, attached to dorsal wall of haemocoel; branched anteriorly and dilated posteriorly (Figure 32: ky); posterior portion of kidney located within pericardial chamber; occupying about 1/3 of haemocoel surface. Nephropores located between last to penultimate ctenidial filaments; posterior to gonopore (Figure 32: gi, ne).

Circulatory system: (Figures 26, 31, 32) Pericardium translucent, located in dorsal surface below valves vii–viii, occupying about 1/10 dorsal inner body surface (Figures 26, 31, 32). Ventricle (Figure 31: ve) elongate, fusiform, anterior region connected to aorta (aa), entirely attached to dorsal surface, ending in valve ii, occupying about 1/10 body volume. Auricles (au) laterally connected through two ducts; anterior duct narrower than posterior one (Figure 31).

Digestive system: (Figures 4, 19–21, 26, 30, 34–39) Labial palp large; mouth surrounded by rounded lip; buccal sphincter muscle (mc) present a unique muscle bundle, surrounding the mouth (mo), flattened, originating in ventral wall of haemocoel, inserting in oral tube, forming the mouth (Figure 27: mc) oral tube short, connecting to buccal cavity as well as dorsal and ventral portions of odontophore (Figure 30). Buccal mass composed of many muscle groups; anterior salivary gland (sg) rounded, irregular, cream colored, placed on anterior portion of buccal mass in different side of odontophore; posterior salivary gland (psg) squared, cream, placed immediately posterior to odontophore cartilage (oc). Dorsal odontophore wall, placed immediately above to radular ribbon, thick, translucent, presenting a pair of dorsal fold (df) elongated antero-posteriorly connected to sg anteriorly. Odontophore muscles (Figures 34, 35, 38, 39) formed by a strong pair of radular muscles (Figures 35, 38, 39: m2), originated on the ventral surface of radula, inserted in valve ii, consisting of numerous muscle bundles, connecting dorsal wall of odontophore to ventral wall of haemocoel. Jugal muscles (Figures 30, 34, 35: mj) composed of a pair of muscles on each side of odontophore cartilage, originating in posterior region of cartilage, extending to and inserting on anterior wall of haemocoel. Dorsal

Figures 10–18. *Acanthopleura gemmata* valves. **9–11**, valve i, dorsal, ventral and right view respectively; **12–14**, valve iii, dorsal, ventral and left view respectively; **15–17**, valve viii, dorsal, ventral and left view respectively. Scales = 2 mm.

dilator buccal muscle (Figures 30, 35: m1d) composed of a pair of slender bundles, located anteriorly to odontophore cartilage, originating on anterior wall of haemocoel, extending towards lateral wall and inserting in the lateral anterior region of cartilage, extending to nearest body wall. Main pair of retractors radular muscles (Figures 30, 34–39: m4) composed of many parallel bundles, originating on ventral surface of odontophore cartilage in four different regions (two median and two posterior) extending immediately to dorsal region of odontophore, inserting below radular cartilage. Ventral buccal dilator muscles of radula (Figures 34, 38, 39: m1v) composed of simple pair of muscle bundles, originate on the posterior portion of the edge of the odontophore cartilage, inserting near posterior lip of mouth. Horizontal muscles (Figures 36, 38, 39: m6) single, transversally arranged, connecting both cartilages along their anterior ventral edge, length about 1/2 cartilage length. Pair of ventral long muscle (Figures 34, 38, 39: m11) very narrow and long, located ventrally, originating at the anterior edge of radular cartilage, extending immediately to lateral portion of radular sac, inserting along posterior third of lateral edges of radular ribbon. The “Y” shaped muscles of radula (Figure 35: m7) originating on dorsal surface of odontophore between both m2, extending toward anterior region, initially fused with each other, bifurcating in exposed (buccal) region of radula, running divergently towards lateral and anterior sides, inserting on mid lateral edges of subradular cartilage. Radula composed of nine teeth columns (Figures 19–21); rachidian teeth narrow, about 5 times longer than wide, width about 1/20 that of radula (Figures19–21); first lateral tooth, long, upper edge concave with width similar to rachidian teeth (Figures 19–21), lower side about 2.5 times wider than upper side; second lateral tooth split, internal portion weakly concave, about 4 times narrower than external portion, more concave and smoother (Figures 19–21); two rows of uncinal teeth inconspicuous; spatulate teeth about 2 times narrower than external portion of second lateral tooth, oriented antero-posteriorly, presenting groove in median portion that extends to lower side (Figures19–21); marginal teeth morphology similar to uncinal teeth, but arranged in three rows (Figures 19–21). Pair of subradular cartilages rounded, thick, translucent, yellowish, extending from median ventral portion of radula and expanding anteriorly; odontophore cartilage projection placed on distal surface, laterally, elliptic, superior portion two to three times narrower than inferior (Figures 4, 36). Pair of odontophore cartilages (Figures 34–39) about 3 times longer than wide, claviform, occupying about 1/3 of odontophore volume; anterior and posterior ends rounded; projection about 5 times smaller than main cartilage located



Figures 19–25. *Acanthopleura gemmata* SEM images. **18–20**, radula, middle portion inside radular sac, scale = 200 µm; **21**, girdle, dorsal view, detail of its middle region of right side, scale = 100 µm; **22**, same, detail of its edge, scale = 100 µm; **23**, same, ventral view, detail of its middle region of right side, scale = 200 µm; **24**, same, scale = 50 µm.

in dorsal end (Figures 36, 37). Esophagus short, wide, presenting three lobes, occupying about 1/3 of buccal mass (Figures 26, 30); Stomach large, distinguishable as a dilated portion just anterior to intestine (Figure 30); Intestine interconnected by simple junction, anterior portion 1.5 times wider, composed of many overlapping loops, antero-posteriorly arranged (Figures 26, 30), connection to rectum gradually tapering, half as narrow as posterior portion of intestine (Figures 26, 30), ending in smooth and circular anus (Figures 26, 30–32).

Genital system: (Figures 26, 31, 31) Gonad elongated antero-posteriorly, flattened, cream colored, dorsal, flanking inner shell surface of valves ii–vi; occupying about 3/10 of visceral mass volume (Figures 26, 31). Gonoduct small, ranging from lateral-posterior wall of gonad to kidney duct, ending in gonopore located between last fourth and fifth ctenidial filaments (Figure 32).

Central nervous system: (Figure 31) Nerve ring simple, surrounding mouth, connected laterally to two parallel cords extending from anterior to posterior ventral surface of visceral mass inside foot (Figure 31).

Measurements (length by width): MZSP 54475 #1: 29.0 x 16.0 mm; #2: 55.0 x 27.2 mm; #3: 41.0 x 18.7 mm; #4: 44.8 x 19.3 mm.

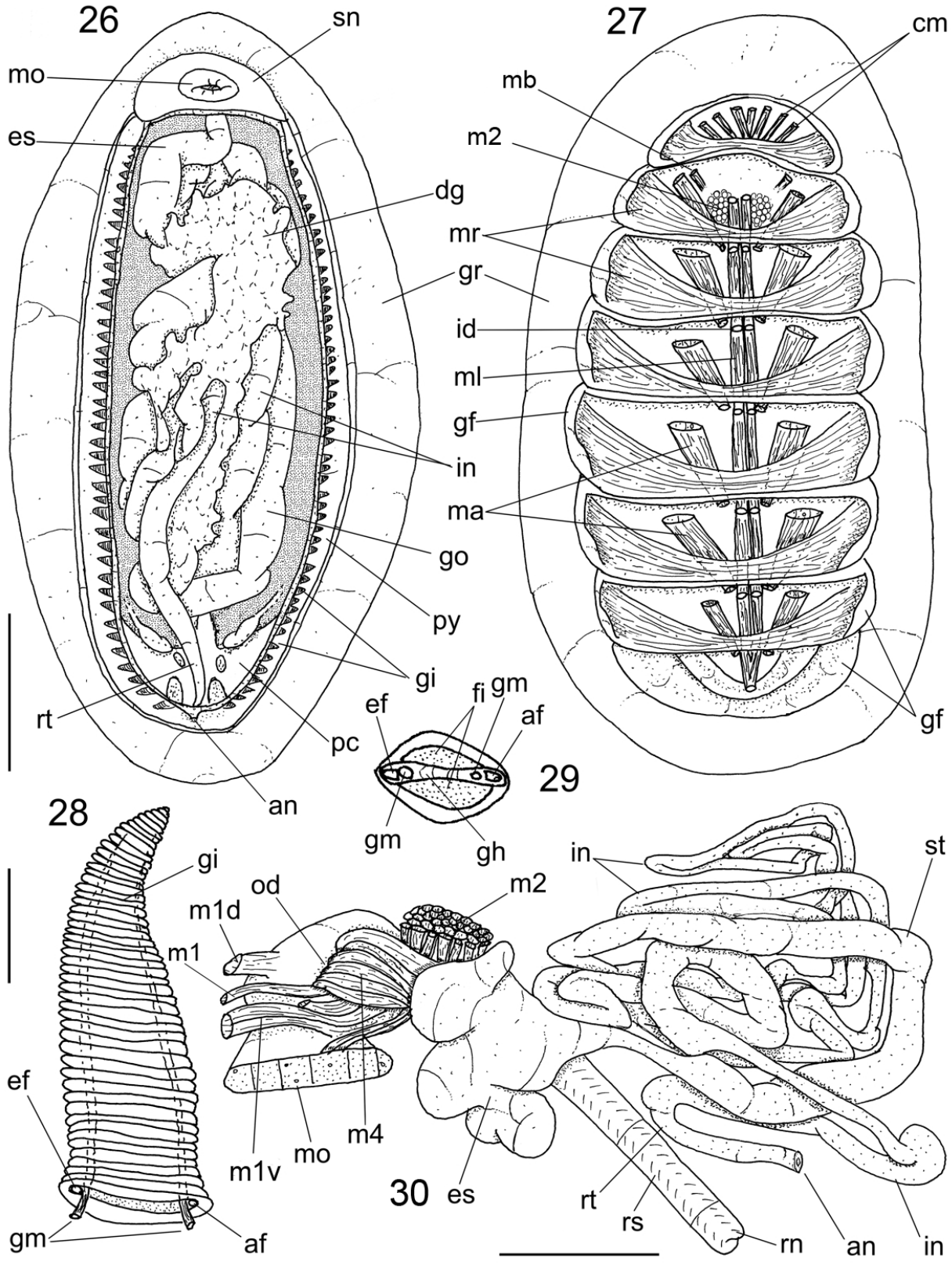
DISCUSSION

Compared to its congeners, *Acanthopleura gemmata* differs from *A. granulata* (Gmelin, 1791) based on literature and specimens housed in MZSP, in having a dorsal surface of the girdle bearing claviform spicules; ventral surface sculptured by tapered rectangular scales with a slightly angulated and keeled distal edge; valves sculptured by rounded and elevated pustules on marginal portion; a circular valve i, with less prominent apices; slender valves ii–vii, with less visible lateral areas; valve viii with a wider, blunt mucro, straight antemucronal area, and a straight postmucronal area and slope. *Acanthopleura gemmata* can be distinguished from *A. spinosa* (Bruguière, 1792) based on literature, by the claviform spicules on the dorsal surface of the girdle; more rounded and wider valves with evident sculpture, exhibiting elevated pustules on marginal portion; larger valve i; valves ii–vii with more oval apophyses, less prominent apices, inconspicuous diagonal ridge, slightly elevated lateral area, wider central area, and a very deep fissure between the apophyses and the insertion plate; valve viii with hardly visible mucro and straight anterior postmucronal area. Moreover, *A. gemmata* differs from *A. echinata* (Barnes, 1824) based on literature and specimens housed in MZSP, by having more rounded valves; narrower and less sculptured valve i; valves ii–vii with less apparent apices, distinguishable (but not well-marked) diagonal ridge, slightly elevated and straight lateral area, and undistinguished pleural and jugal areas; more oval valve viii, with superior mucro, straight antemucronal area and sloped postmucronal area. *Acanthopleura gemmata* differs from *A. loochooana* (Broderip & Sowerby, 1829) based on literature, in presenting squarer valves; more oval and narrower valve i; valves ii–vii with less preeminent apices, less visible diagonal ridge, less visible lateral area, and less prominent central area; valve viii with slightly superior mucro, straight antemucronal area, and an inclined and straight postmucronal area. *Acanthopleura gemmata* can be told apart from *A. brevispinosa* (Sowerby, 1840) based on literature and specimens housed in MZSP, by the dorsal surface of the girdle composed of strong claviform spicules; valves well sculptured at marginal portion and less elevated; rounder and wider valve i; wider valves ii–vii, with less evident apices, inconspicuous diagonal ridge, slightly elevated lateral area, smooth central area, undistinguished pleural and jugal areas; more oval valve viii with anterior mucro, straight antemucronal area, angulated and straight postmucronal area.

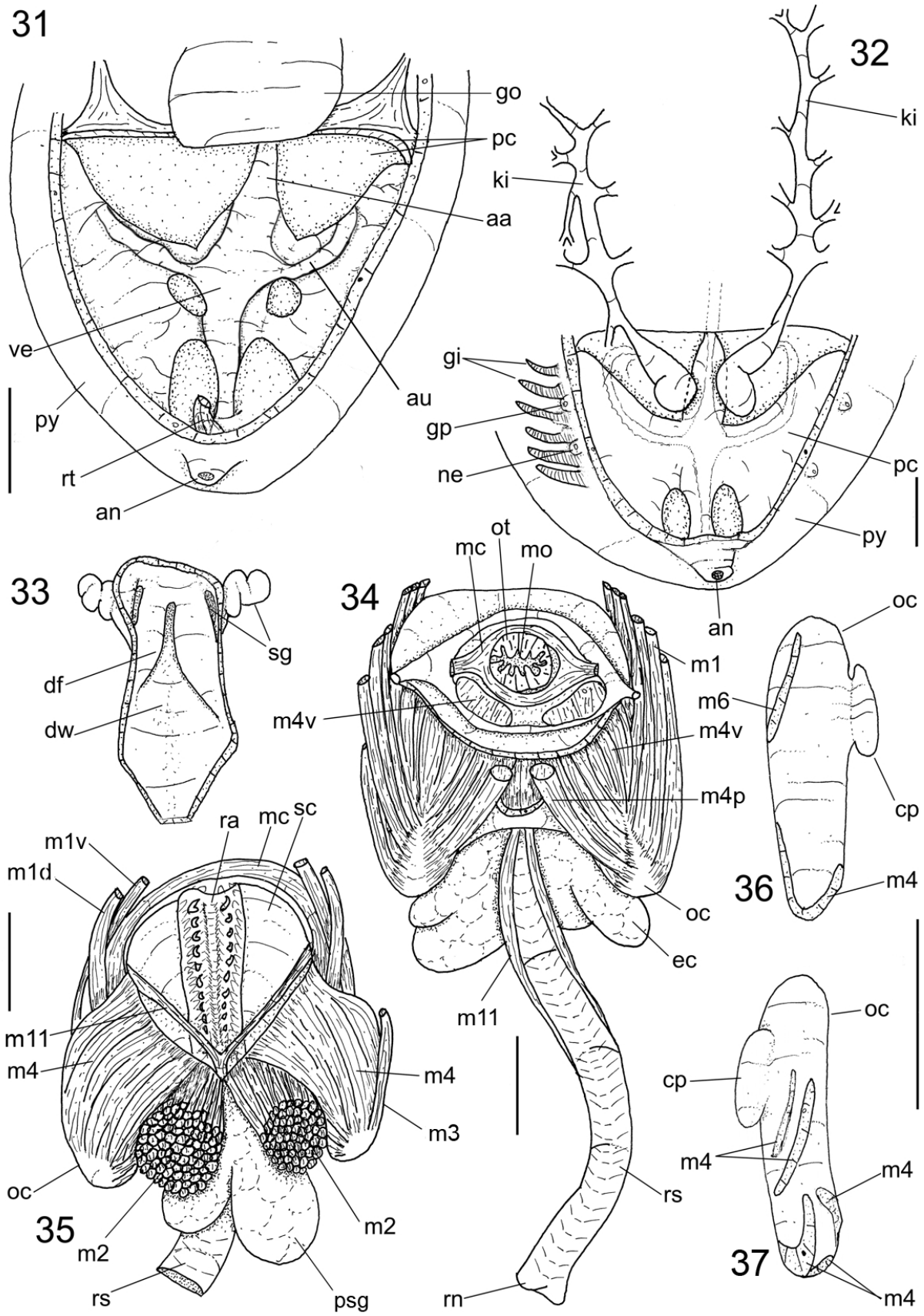
Comparing *Acanthopleura gemmata* with *Hanleya brachyplax* Jardim & Simone (2010), *A. gemmata* differs for the posterior margin V-shaped; presence of slits in valve I; preoral muscle formula 3/1/3; presence of anterior oblique muscle (mb); transverse muscle (mt) connected in all valves; straight muscle extending from valves ii-viii; ctenidial filaments holobranchial; kidney in pair, elliptic; esophagus complex with chambers; odontophore cartilage elliptic on anterior portion. On the other hand, *H. brachypalx* presents posterior margin of valve i nearly straight; insertion plates not fissured; preoral muscle formula 2/2; transverse muscle connected in valves iii-vii; straight muscle extended from valves ii-vii; ctenidia filaments merobranchial; kidney unique, triangular; esophagus complex without chambers; m4a, m5, m11a and m3 presents and odontophore cartilage squared on anterior portion.

Barbosa *et al*. (2010) studied developmental aspects of *A. gemmata* from One Three Reef. Considering the growth rates suggested by Barbosa *et al*. (2010), one specimen studied herein fits in the medium class and three others can be classified as large. The location of the ctenidial vessels of the specimens studied herein agrees with the description by Hunter & Brown (1965) it but differs slightly regarding the size.

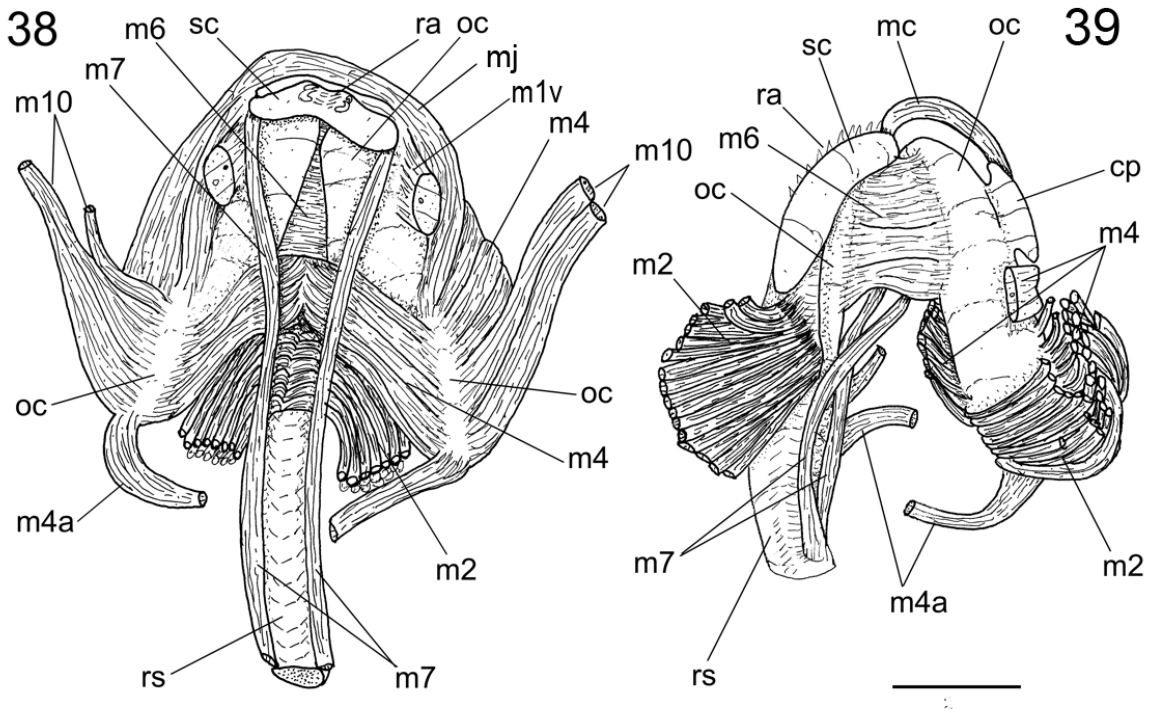
In the present specimens, the median dorsal muscle (Figure 26: ml) extends itself from the valves ii to viii. This is different from the condition reported by Sampson (1894) and Kaas *et al*. (2006), who mentioned the same muscle ranging from valves i to viii. This study, as well as Sampson's (1894), reports the regions of fixation of the dorsal muscle on the ventral surface of the valve, differing from Kaas *et al*. (2006), who did not mention it whatsoever.



Figures 26–30. *Acanthopleura gemmata* anatomy. **25**, whole ventral view, foot removed, structures from haemocoel seen as in situ, scale = 5 mm; **26**, whole dorsal view, valves removed, main concern to muscular system; **27**, isolated ctenidial filament, scale = 10 mm; **28**, same, transverse section in its base; **29**, digestive tract as in situ, left view, intestinal loops somewhat separated from each other, scale = 2 mm.



Figures 31–37. *Acanthopleura gemmata* anatomy. **30**, region of pericardium, ventral view, ventral wall of pericardium removed and deflected upwards; **31**, reno-pericardial system, ventral view, topology of some adjacent structures also shown; **32**, dorsal wall of buccal mass, ventral view; **33**, buccal mass, ventral view; **34**, same, dorsal view, dorsal wall removed; **35**, right odontophore cartilage, median view, insertion of muscles shown; 36, same, outer view. Scales = 2 mm.



Figures 38–39. *Acanthopleura gemmata* odontophore. **37**, ventral view, some extrinsic muscles deflected; **38**, dorsal view, radular ribbon deflected to left, right muscles mostly deflected to show cartilage. Scales = 2 mm.

The transverse muscle (Figure 27: mr) is herein considered as a distinct component of the main muscle group, originating in the **gf** and inserted into the opposite side of the same muscle. It has a typical U-shape, with a median portion two to three times narrower than the lateral portion. This differs from the observations of Sampson (1894), who reported this structure as an indistinct "*cushion*" of muscles, instead describing it as narrower and originating in the **mr** of Kaas & Van Belle (1985). Kaas *et al*. (2006) described the **mr** as the root of the muscle and did not address its expansions.

The anterior oblique muscle (Figure 27: mb) is present exclusively in the first valve ii in our specimens, differing from Sampson (1894) and Kaas *et al*. (2006), who reported this muscle, as located exclusively in valve viii. The oblique muscle (Figure 26) is shorter than mentioned by Sampson (1894) and Kaas *et al*. (2006), covering three quarters of the dorsal surface of the valves ii–vii.

The radular muscle (Figure 27: m2) follows the pattern described by Sampson (1984), though Kaas *et al*. (2006) did not mention it. The crossed muscle described by Sampson (1894), however, is absent in our specimens. The horizontal muscle corroborates to describe by Wingstrand (1985), connecting odontophore cartilage on superior portion, rectangular (Figure 36: m6, oc). On the other hand, the dorsal buccal dilator and ventral dilator muscles (Figures 30, 34, 35: m1v, m1d) are partially in agreement with Sampson (1984) due to not being attached to the valve i. They are instead attached to the body wall, under valves i and ii. The radular retractor muscle (Figures 30, 34, 35: m4) are in part like those described by Sampson (1894), as the main radular group system is composed of independent circular bundles and is not an exclusive feature of this muscle group. The Y-shaped muscle of the radula (Figure 35) compares well with the description by Sampson (1894). The odontophore cartilage (Figures 34–37: oc) is in partial agreement with Sampson's (1894) description but differs here in a lateral extension located on the external side. The mouth has circular muscles in the lip, and the buccal sphincter muscle (Figures 30, 34: mo, mc) agrees with Sampson's (1894) report.

Comparing the data obtained here with that reported by Wingstrand (1985), most of the observations are congruent, but some muscle groups are slightly different. This is the case in the preoral muscle (Figure 27: cm), which originates immediately under the radular muscle and extends along three quarters of the dorsal wall and has no connections with the lateral longitudinal muscle. It also does not have an extension to the dorsal wall of the animal. The longitudinal muscle (Figure 27: gf) showed a unified structure, with re-

inforcements under each valve. The radular muscle (Figures 30, 35, 38, 39: m2) follows Wingstrand's (1985) description, but the ventral bundle is absent.

Yonge (1939) described some aspects of the mantle cavity of *Acanthochitona crinita* (Pennant, 1777). He defined the mantle cavity as composed of a lateral pallial cavity connected to the posterior side, but the specimens studied herein present a connection to both the posterior and the anterior regions. This disagrees partially with Yonge's observation in that the anterior connection is present on the dorsal surface of the snout. The division of the pallial groove into inhalant and exhalant chambers in our specimens agrees with Yonge's description. However, the fold of the girdle mentioned by Yonge (1939) is only partially confirmed here, for we are inclined to believe that the shape of this structure can be modified depending on the preservation methods employed. The location of the reproductive pores mentioned by Yonge (1939) differs from our observations. He described the gonopore as located posteriorly to the fourth ctenidia filament from the posterior portion, and the excretory pore as located after the second ctenidia filament from the gonopore. Yonge further described a pair of muscles called "longitudinal muscles" present in the ctenidia filaments. We do not use this nomenclature because the name is already in use as a muscle placed on the dorsal surface of the chiton. For this reason, the authors will call it ctenidia muscles.

Kaas & Van Belle (1985) briefly described the circulatory system for chitons generally. Our observations agree completely with their descriptions. Sedgwick (1881) described and discussed kidney morphology in chitons. The material observed here agrees partially with Sedgwick's descriptions: the kidney observed in our specimens presents dilatation as expected, but the connections with the body are restricted to the anterior portion of the kidney, where numerous branches stemming from it extend to all of the animal's body. Any branches on the posterior or lateral portions as mentioned in Sedgwick (1881), are absent in our specimens. The kidney studied here presents a unified structure composed of two dilated portions: the posterior wider and shorter than the anterior portion. Names, such as kidney secreting tubules, and kidney ducts were not used herein, since we understand these are pointless subdivisions of a major, already named structure.

Barbosa *et al*. (2009) described reproductive anatomy in *A. gemmata* sampled from Great Barrier Reef. Barbosa *et al*. mentioned the color of the gonad as important to sex determination. We do not agree with this observation, since some of our specimens presented an exclusively monochromatic cream-colored gonad. Moreover, it is not possible to confirm if the color of the gonad results from the juvenile stage of specimens or an artifact generated by the fixation process. Though we had analyzed only three specimens sampled from Thailand, the range of color reported by Barbosa *et al*. (2009) was not confirmed herein.

The general morphology of the digestive system reported by Fretter (1936) mostly agrees with our data. However, the salivary glands (Figure 33: sg) observed in our specimens agree partially with Fretter's (1936) description. The ciliate groove, mucous gutter, and salivary gland were considered parts of the salivary gland. The anterior esophageal pouch, the fold dividing posterior esophageal pouch, posterior esophagus, anterior lobe of sugar gland, the duct of the sugar gland, glandular ridge and posterior lobe of the sugar gland region are here named buccal mass, due to the lack of any differentiation that could justify the indication of these names. The ventral sac of the stomach (Figures 26, 30: es), as mentioned by Fretter (1936), is identified here as the esophagus, but otherwise agrees with Fretter's description. The duct of the anterior liver lobe and the duct of posterior liver lobe were not observed herein. Though we did not perform a histological analysis, we have concentrated our efforts exclusively on anatomical details, which indicated that the dilated (anterior) portion of the intestine was a consequence of the presence of microvilli on its entire inner surface, and the tissue thus became thicker in relation to the posterior portion. The transverse and longitudinal ciliated bands were not observed herein. As mentioned above, we set off from the premise that the anterior and posterior intestines described by Fretter (1936) are a unique structure indicated as the intestine.

The present concept of *Acanthopleura gemmata* has been challenged by molecular studies, have indicated that it includes several cryptic species (Brooker 2003). The present paper provides a detailed description of a sample collected in Thailand, where the presence of this species was never previously reported. Future studies can be conducted in order to perform an equivalent investigation of samples from other localities. Differences in the inner anatomy can be added to genetic differences, which may further endorse future specific separations.

The accepted geographical distribution of *Acanthopleura gemmata* extends from 32°E to 33°N, and from 1°S to 177°W. It includes the Mediterranean Sea (Ferreira 1983); Gulf of Aqaba (Saudi Arabian) (Ferreira 1983); Persian Gulf (Ferreira 1983); Red Sea (Sudan, Eritrea, Somalia, Kenya, Tanzania,) (Ferreira 1983); Seychelles Island (Ferreira 1986); Comoro Islands (Ferreira 1986), Gulf of Oman (Masqat) (Ferreira 1983); Pakistan (Karachi) (Ferreira 1983); Gulf of Aden (Yemen, Socotra Island) (Ferreira 1983); Mauritius (Viader 1937;

Leloup 1941; Ferreira 1986); Réunion Island (Deshayes 1863; Ferreira 1986); Glorioso Is., Toliara, Nosy Sakatia (Nosy Iranja) (Ferreira 1983); Arabian Sea, Bay of Bengal (Leloup 1952); India (Nicobar Island) (Satyamurti 1952), China (Taiwan, South Chinese Sea), Japan (Izu Islands and Amami Islands), Taiwan, Philippines and Western Pacific (Higo *et al*., 1999), Singapore (Tan & Woo 2010), Australia [Western Australia - Tree Hummock Island, Shark Bay, Queensland (Great Barrier Reef, Dunk Island, Port Curts) to New Holland Coasts], Micronesia (Carolinas Island, Marquesas Island), and Mariana Island (Leloup 1941), New Caledonia (Heros *et al*. 2007), Samoa (Ministry of Natural Resources and Environmental, Conservation International Pacific Island Programme 2017). It is quite possible that several more restricted species are in fact grouped in this assembly, and this issue is still under analysis. The present paper is thus a first step towards better understanding this widespread taxon.

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