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Intertidal chitons (Mollusca: Polyplacophora) from southern Madagascar

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ABSTRACT

This paper focuses on five species of Polyplacophora (Mollusca) collected from Lavanono, southern Madagascar. *Ischnochiton sirenkoi* is described as a new species and is compared with the two *Ischnochiton* species known from Madagascar, *I. yerburyi* (E.A. Smith, 1891) and *I. sansibarensis* Thiele, 1909, and with all known Indian Ocean *Ischnochiton* species. Findings for the other species here discussed provide a significant extension of previously known geographical range. *Chaetopleura chelazziana* Ferreira, 1983 is reported for the first time in the chiton fauna of Madagascar. The taxonomic status of *Callistochiton ashbyi* (Barnard, 1963), previously considered a synonym of *C. crosslandi* Sykes, 1907, is discussed. This taxon, which was described from a unique intermediate valve from South Africa, is re-evaluated and recognized as a valid species, differing from *C. crosslandi* in several significant characters. We also present an unusual feature detected in almost all the specimens of *Cryptoplax dupuisi* Ashby, 1931, which are characterized by the absence of dorsal girdle spicules on the first four valves, a feature never reported in other chiton species. Type material of *Callistochiton madagassicus* Thiele, 1909, *Chiton ashbyi* (Barnard, 1963) is figured.

KEYWORDS: Mollusca, Polyplacophora, Madagascar, Lavanono, taxonomy, Indian Ocean, marine, new species.

INTRODUCTION

Within the Indo-Pacific biodiversity and biogeography, the marine fauna of Madagascar is particularly significant because of the presence, off Tuléar, of one of the world's longest reefs (Spalding *et al*. 2001). In recent years, the chiton fauna of Madagascar has been the subject of a number of studies, resulting in a better appreciation of the taxonomy of some particularly elusive species and in a reconsideration of their geographic distribution (Leloup 1981; Kaas 1986; Dell'Angelo *et al*. 2004*b*, 2010*b*). Nevertheless, a comprehensive study of Malagasy chitons has yet to be achieved, and finding new material allows us to present new information. During ongoing research on the marine mollusca that inhabit the southern Madagascar coasts, one of us (GP) has come across many specimens of chitons, some of which belong to a new species of *Ischnochiton*, and others of species either rarely reported or unrecorded from this area.

MATERIAL AND METHODS

The studied material was mostly collected in 2007/09 by Giovanni Prelle (Torino) at Lavanono, a locality in southern Madagascar, 40 km from Cape St Marie and 60 km from Faux Cap, 25°25'43"S:44°56'19"E (Fig. 1). The specimens were mainly collected from under small, smooth pebbles on reef, at a depth of 0.1–0.4 m.

Specimens used for SEM were disarticulated, to enable the examination of valves, perinotum, and radula. Micrographs were taken using a JEOL 5200 SEM (at the MZB).

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The higher classification used below follows Sirenko (2006).

Abbreviations:

BD – Bruno Dell'Angelo collection (Genova, Italy);
BMNH – The Natural History Museum, London, United Kingdom;
CASC – California Academy of Sciences, San Francisco, California;
GP – Giovanni Prelle collection (Torino, Italy);
MNHN – Muséum National d'Histoire Naturelle, Paris, France;
MZB – Museo di Zoologia dell'Università di Bologna, Italy;
MZUF – Museo di Zoologia dell'Università di Firenze, Italy;
NMSA – KwaZulu-Natal Museum, Pietermaritzburg, South Africa;
SAMA – South Australian Museum, Adelaide, Australia;
SAMC – South African Museum, Cape Town, South Africa;
ZISP – Zoological Institute of the Russian Academy of Sciences, St Petersburg, Russia;
ZSM – Bavarian State collection of Zoology, Germany.



Fig. 1. Collecting locality (Madagascar, Lavanono).

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TAXONOMY

Class Polyplacophora Gray, 1821
Subclass Loricata Schumacher, 1817
Order Chitonida Thiele, 1909
Suborder Chitonina Thiele, 1909
Family Ischnochitonidae Dall, 1889
Genus *Ischnochiton* Gray, 1847

Ischnochiton: Gray 1847*a*: 126. Type species (by subsequent designation of Gray 1847*b*: 168): *Chiton textilis* Gray, 1828; Recent, South Africa.

For synonymy, see Kaas & Van Belle 1990.

Distribution: Worldwide, widespread in all seas, except for the northern Atlantic and Arctic oceans; Eocene–Recent.

Ischnochiton sirenkoi sp. n.

Figs 2, 4A, 4B

Etymology: The specific name honours our friend Dr Boris Sirenko (ZISP), for his contribution to the study of Recent and fossil chitons.

Diagnosis: Animal elongate-oval, of medium size, moderately elevated, subcarinated, valves not beaked, lateral areas not raised. Colour highly variable. Tegmentum sculptured with large irregular pustules, arranged in segments of various sizes and shapes, becoming longitudinally elongate in pleural areas. Mucro not elevated, submedian. Slit formula 9-10/1/8-10. Dorsal girdle scales imbricated, sculptured with 27 or 28 narrow riblets. Ventrally with radiating rows of elongate, rectangular, smooth scales. Radula with bicuspid head of major lateral tooth, minute granulations on upper surface of cusps.

Description:

Animal of medium size, holotype 12.2×6.1 mm, maximum size 17.6×8.2 mm, elongate-oval, moderately elevated (dorsal elevation 0.34), subcarinated, valves not beaked. Colour of tegmentum very variable, whitish with pale brown and black flecks, greenish with darker flecks mainly on jugal areas, evenly reddish brown, or marbled with irregular spots of various colours. Girdle colour resembles tegmentum, uniform or in neatly alternating bands.

Head valve semicircular, front slope straight, posterior margin widely V-shaped (Fig. 2A). Intermediate valves broadly rectangular, front margin slightly concave in wide central part between apophyses (slightly convex in valve ii), straight or slightly concave in lateral parts, side margins rounded, hind margin almost straight, apices inconspicuous, lateral areas not raised, poorly defined (Fig. 2F). Tail valve semicircular, front margin strongly concave in wide central part between apophyses, mucro not elevated, submedian (Fig. 2K), antemucronal slope convex, postmucronal slope concave directly behind mucro (Fig. 2L).

Tegmentum of head valve, lateral areas of intermediate valves and postmucronal area of tail valve sculptured with large, rather raised and very irregular pustules, arranged in segments of various size and shape, i.e. triangular, rectangular, rounded or sinuous, slightly overlapping each other, giving a wavy aspect (Figs 2D, 2O). Segments in pleural areas (Fig. 2I) become longitudinally elongate, always very irregular, sinuose and

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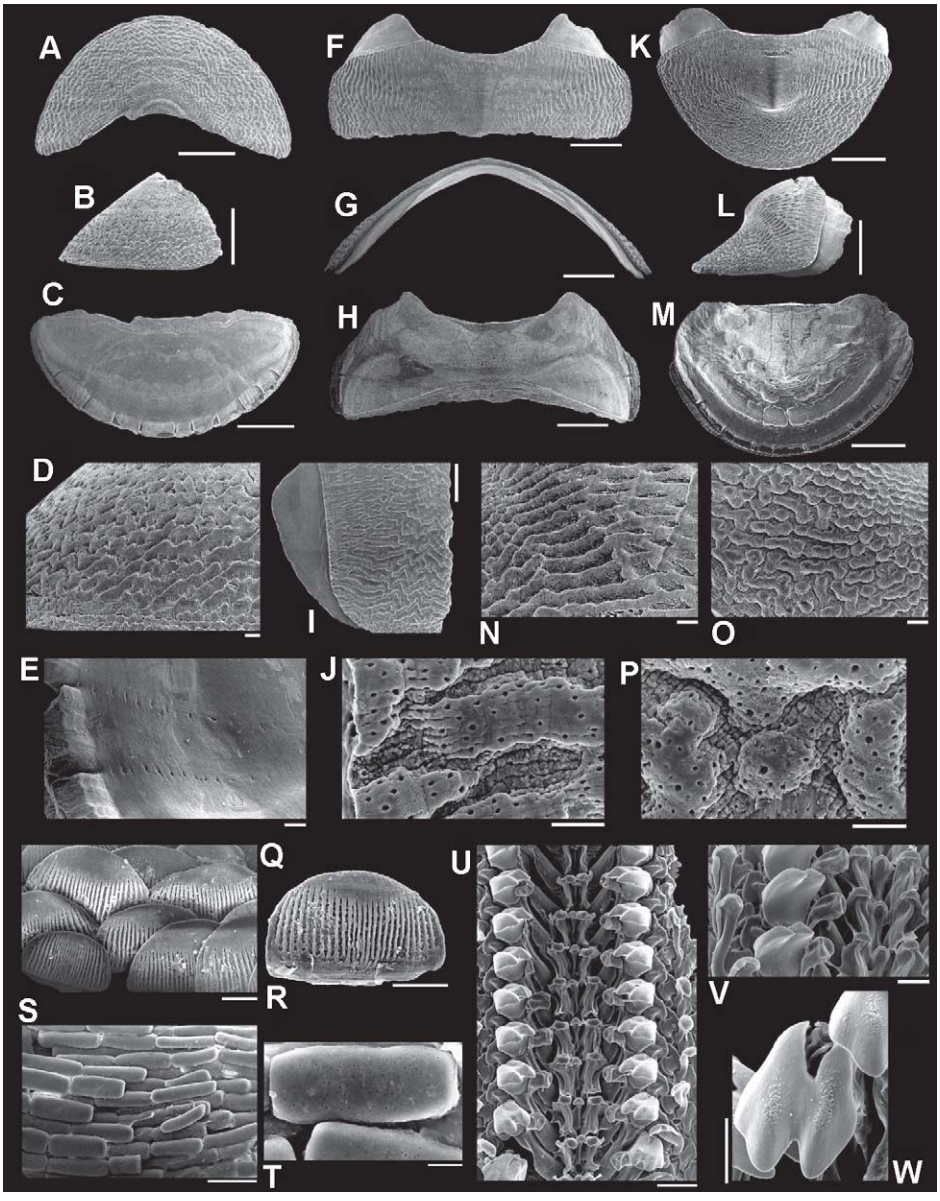


Fig. 2. *Ischnochiton sirenkoi* sp. n., paratype, MZB 45695: (A–E) head valve, (A–C) dorsal, lateral and ventral views, (D) detail of the sculpture, (E) detail of teeth and slit rays of the articulamentum; (F–J) intermediate valve: (F–H) dorsal, frontal and ventral views, (I) detail of the sculpture of the tegmentum, (J) pustules with aesthetes, in pleural area; (K–P) tail valve: (K–M) dorsal, lateral and ventral views, (N) detail of the sculpture of the tegmentum, at the contact between postmucronal (at the left) and antemucronal areas, (O) detail of the sculpture of the tegmentum of postmucronal area, (P) pustules with aesthetes, in postmucronal area; (Q–T) girdle elements: (Q, R) dorsal scales, (S, T) ventral scales (note the small holes on the surface); (U–W) radula: (U) complete view, (V) detail of an half row of teeth, (W) bicuspid head of the major lateral tooth (note the minute granulations present on the upper surface of the cusps). Scale bars 1 mm (A–C, F–H, K–M), 500 μm (I), 100 μm (D, E, N, O, U), 50 μm (J, P–S) and 10 μm (T).

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intersecting each other, giving the appearance of a network of irregular and elongate pits. This sculpture becomes less evident close to the jugal area, which is practically smooth. Many aesthetes irregularly present on pustules' surface (Figs 2J, 2P).

Articulamentum well developed, whitish, apophyses evenly rounded, jugal sinus wide, slit formula of insertion plates 9-10/1/8-10, slits inequidistant, slit rays distinctly punctured, teeth sharp, smooth, eaves solid (Fig. 2E). Jugal tract of intermediate and tail valves with numerous transverse slits.

Girdle dorsally clothed with small, round-topped, strongly curved, imbricating scales, 103 μm long, 143 μm wide (Fig. 2Q), sculptured with 27 or 28 narrow riblets (Fig. 2R), riblets much less pronounced on upper part of scales, interstices slightly wider than ribs. Ventral side covered with radiating rows of elongate, rectangular, smooth scales, *ca* 58–70×10–13 μm (Fig. 2S). At high magnification, surface of these small scales covered with small holes (Fig. 2T).

Central tooth of radula narrow, bearing roundish, outwardly curved blade, first lateral tooth equally narrow, with outwardly curved blade, major lateral with bicuspid head, denticles pointed of the same size, minute granulations on upper surface of cusps (Fig. 2W).

Ctenidia arranged holobranchially and abanally.

Comparison and remarks: This is a very variable species but clearly distinguishable from the other two species of *Ischnochiton* currently known from Madagascar (Kaas & Van Belle 1990): *I. yerburyi* (E.A. Smith, 1891) and *I. sansibarensis* Thiele, 1909 (reported as *I. rufopunctatus* Odhner, 1919 by Odhner 1919; Dautzenberg 1923, 1929). The colour of the new species is very variable (Fig. 4B), both glossy and dull, mostly greenish and more or less uniform, or with colour flecks mainly on the jugal area, but also evenly white, or reddish (from brownish to red to violet) with various spots of colour, which are rarely blackish. Also the pleural areas sculpturing is variable, lighter in some specimens, and more evident near a band up the lateral areas or near the side margins of the intermediate valves, leaving a large central part of the valve smooth. The sculpture of *I. sirenkoi*, is very different to that of *I. yerburi* and *I. sansibarensis*. *I. yerburyi* has a reticulated, thimble-like sculpture pattern on all valves. We examined the type of *I. sansibarensis* (Fig. 4C) at the ZMB (Kilias 1995); it is not in a good state of preservation, but the thimble-like sculpture is still clearly visible. In this species the sculpture is much weaker on the central areas, with the head valve, lateral areas of intermediate valves and postmucronal area of the tail valve evenly quincuncially granulated. Ferreira (1983) considered *I. sansibarensis* to be a synonym of *I. yerburyi*, but we agree with Kaas and Van Belle (1990), who examined the types of all Indian Ocean *Ischnochiton* species with a thimble-like sculpture, that the two species can be distinguished. In addition to the different sculpture in these taxa, they also differ in size (*I. yerburyi* maximum 15×8 mm; *I. sansibarensis* 10×5.5 mm; *I. sirenkoi* 17.6×8.2 mm), their girdle dorsal scales (24 or 25 riblets in *I. yerburyi*, 13–15 in *I. sansibarensis*; 27 or 28 in *I. sirenkoi*), and the ornamentation of the upper surface of the cusps of the major lateral teeth of the radula that in *I. sirenkoi* shows a characteristic granulation. This granulation on the radula is rarely seen in chitons, although this may reflect a lack of detailed examination in other chiton species.

The new species differs from other *Ischnochiton* species living in the Indian Ocean.

I. winckworthi Leloup, 1936, known from the Arabian Sea and the Bay of Bengal, has a stronger, more granulose sculpture, forming irregular, radiating granulose riblets in the head valve, the lateral areas of intermediate valves, and the postmucronal area of tail valve.

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I. indianus Leloup, 1981 known from the Mozambique Channel and KwaZulu-Natal has a mainly smooth tegmentum, with only a few fine longitudinal grooves near the front margin of the latero-pleural parts of the intermediate valves.

I. feliduensis E.A. Smith, 1903 from the Maldive Islands, *I. bouryi* Dupuis, 1917 from the Andaman Islands, Pakistan, Sri Lanka and Indonesia, *I. gallensis* von Knorre, 1925 from Sri Lanka and Krusadai Island, *I. crassus* Kaas, 1985 from the Mozambique Channel, *I. bigranosus* Kaas & Van Belle, 1990 from the Andaman Islands, *I. yemenensis* Van Belle & Wranik, 1994 from Yemen and *I. goudi* Kaas, 1994 from the Seychelles Islands are different species, not comparable with *I. sirenkoi*.

Of the *Ischnochiton* species living along the South African coast, two can be compared with *I. sirenkoi*, i.e. *I. oniscus* (Krauss, 1848) and *I. elizabethensis* Pilsbry, 1894). These species were recently studied by Sirenko and Schwabe (2002), and differ from *I. sirenkoi* mainly in having a different, more granulated, sculpture and in the shape of the major lateral tooth of the radula (tricuspid in *I. oniscus*, unicuspid in *I. elizabethensis*, bicuspid in *I. sirenkoi*).

Holotype: MZB 45693, length 12.2 mm (Fig. 4A). MADAGASCAR: Lavanono.

Paratypes: same data as holotype, 2 specimens without soft parts, largest 13.8 mm, smallest 11.7 mm (MZB 45694); 1 specimen coated and dismounted for SEM analysis (Figs 2A–W) (MZB 45695); 1 specimen, length 15.5 mm (MNHN); 1 specimen, length 14.5 mm (BMNH); 1 specimen, length 12.7 mm (NMSA); 1 specimen, length 16.2 mm (ZISP 61115); 1 specimen, length 16.7 mm (ZSM Mol 20100376); 2 specimens, length 14.8 and 15.5 mm (GP); 2 specimens, length 14 and 15 mm (BD).

Other material examined: 10 specimens (GP), 4 specimens (BD), 1 specimen (ZSM Mol 20100377), all from the type locality.

Distribution: Madagascar, Lavanono.

Family Callistoplacidae Pilsbry, 1893

Genus *Callistochiton* Carpenter in Dall, 1879

Callistochiton: Dall 1879: 297. Type species: *Callistochiton palmulatus* Carpenter in Dall, 1879, by monotypy.

For synonymy, see Kaas & Van Belle (1994).

Distribution: Tropical and subtropical waters. Paleogene – Recent.

Callistochiton ashbyi (Barnard, 1963)

Figs 3A–P, 4D–F

Chiton ashbyi: Barnard 1963: 343, fig. 29m; 1974: 741; Kaas 1979: 860 (in synonymy of *Callistochiton crosslandi*); 1986: 13 (in synonymy of *C. crosslandi*); Leloup 1981: 14, 17; Giles & Gosliner 1983: 2; Kaas & Van Belle 1994: 138 (in synonymy of *C. crosslandi*).

Description:

Animal of moderate size, up to 27×14 mm, moderately elevated, back evenly arched, not carinated, valves not beaked. Colour of tegmentum and girdle uniform pale ochraceous to yellowish.

Head valve semicircular, little elevated, anterior slope slightly convex, posterior margin widely V-shaped with rounded notch at apex (Fig. 3A). 11 or 12 rounded radial ribs of different widths, not split, separated by narrow interstices, not reaching apex, tegmentum very finely granulated, ribs ornamented with large nodules (10–15), which become less pronounced towards apex (Fig. 3B).

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Intermediate valves broadly rectangular, anterior margin convex, posterior margin straight, side margins strongly bilobate, apices usually worn away (Fig. 3G). Lateral areas distinctly defined, sculptured like head valve, two nodulose ribs of about equal width, separate by narrow, deep sulcus. Central area sculptured with 23–27 longitudinal, elevated, granulose riblets (Fig. 3H); many riblets in central part of the valve strongly ramifying, riblets on jugum are less defined, with narrow interstices, not reaching apex. If not eroded, apical region finely reticulated.

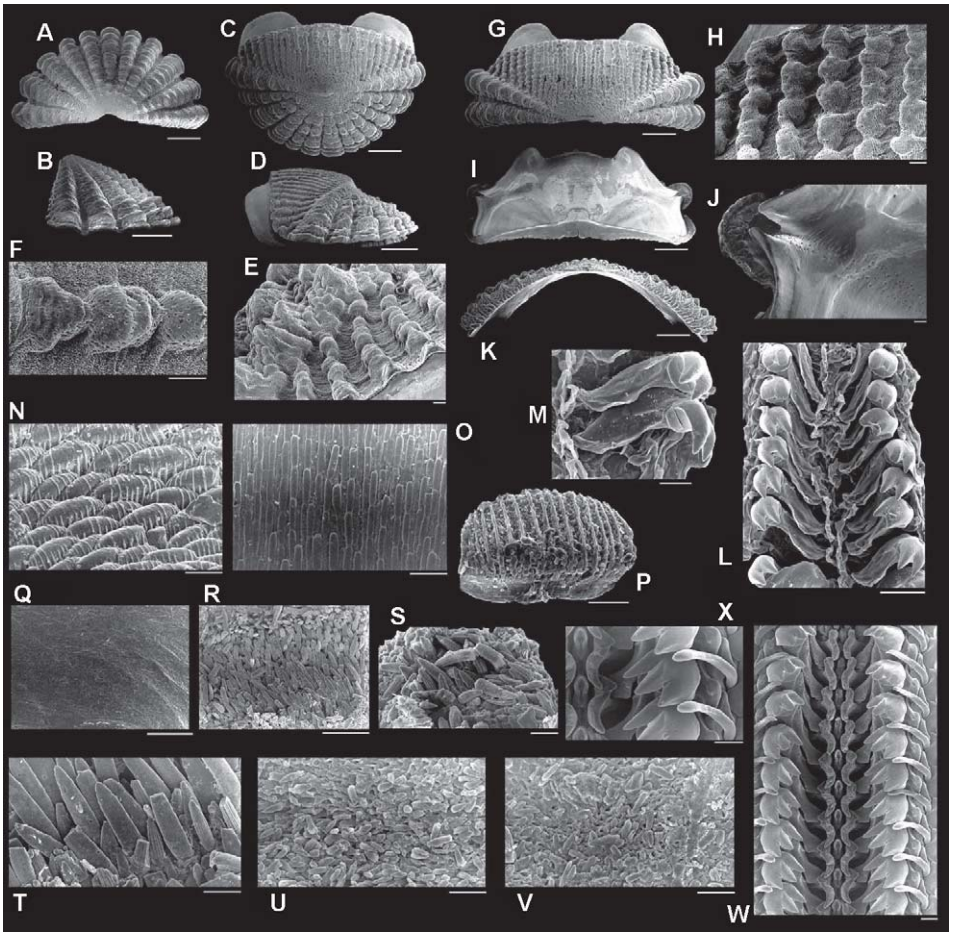


Fig. 3. (A–P) *Callistochiton ashbyi* (Barnard, 1963), Lavanono, Madagascar, specimen n. 6 (Table 1), MZB: (A, B) head valve, dorsal and lateral views; (C–F) tail valve: (C, D) dorsal and lateral views, (E) detail of the sculpture of antemucronal area, (F) detail of longitudinal, granulose riblets; (G–K) intermediate valve: (G) dorsal view, (H) detail of longitudinal, granulose riblets of pleural area, (I) ventral view, (J) detail of slit, (K) frontal view; (L, M) radula: (L) complete view, (M) detail of central, first lateral and major lateral teeth, with the bilobed blade; (N–P) girdle elements: (N) dorsal scales, (O) ventral scales, (P) a single dorsal scale; (Q–X) *Cryptoplax dupuisi* Ashby, 1931, Lavanono, Madagascar: (Q–V) girdle elements: (Q) "naked" dorsal girdle, in correspondance of valves i–iv, (R) "normal" dorsal girdle of valves v–viii, (S) dorsal spicules, (T) marginal spicules, (U) ventral spicules on valves i–iv, (V) ventral spicules on valves v–viii; (W, X) radula: (W) complete view, (X) detail of an half row of teeth. Scale bars 1 mm (A–D, G, I, K), 500 μm (Q, R), 100 μm (E, F, H, J, L, N, O, S–X) and 50 μm (M, P).

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Tail valve with mucro almost central, small, sharp (Fig. 3C), postmucronal slope concave (Fig. 3D). Antemucronal area sculptured like central areas, postmucronal area sharply differentiated with 12–16 strong, nodulose, radial ribs; ribs of differing widths, some ribs splitting, bearing a few tubercles near outer margin.

Articulamentum white, insertion plates well developed, apophyses short and trapezoidal, more triangular in valve ii. Slit formula 9/1/9, slits deep (Fig. 3J), teeth irregular, smooth, broad, somewhat scalloped.

Girdle moderately wide, dorsally densely clothed with strongly imbricating, round-topped scales, up to 228×145 μm (Fig. 3N), sculptured with 12–15 very fine riblets (Fig. 3P). Ventral scales flat, smooth, elongate rectangular, *ca* 85–100×18–25 μm, arranged in radiating rows (Fig. 3O).

Central tooth of radula very slender, parallel-sided, first lateral tooth equally narrow, major lateral tooth with bilobed blade (Fig. 3L), with two denticles of same dimensions.

Ctenidia arranged holobranchially.

Comparison and remarks: Three *Callistochiton* species were previously recognized from Madagascar: *C. crosslandi* Sykes, 1907, *C. barnardi* Leloup, 1981, and *C. rotondus* Leloup, 1981 (Kaas & Van Belle 1994). These authors and Kaas (1979), included *C. madagassicus* Thiele, 1909 from Madagascar, and *Chiton ashby* Barnard, 1963 from South Africa as synonyms of *C. crosslandi*, which was described from a single specimen from Kenya (presumed lost, Kaas & Van Belle 1994).

While Kaas (1979) recognised differences between *C. madagassicus* (holotype MNHN, Fig. 4G) and *C. crosslandi*, he regarded the former as a synonym of the latter. The unique intermediate valve type of *Chiton ashbyi* (Figs 4E, 4F) differs from either of these, but agrees completely with the Lavanono material (Table 1), which is therefore identified as *Callistochiton ashbyi*. This species differs from *C. crosslandi* in several significant characters – the radial ribs of the head valve are never bifid, the greater number of longitudinal ribs on the intermediate valves, and the smaller number of radial ribs on the tail valve.

Considering how few specimens of *C. crosslandi* and *C. madagassicus* have ever been recorded, the 20 specimens of *Callistochiton ashbyi* found at Lavanono are a

TABLE 1

Comparison of characters of *C. crosslandi*, *C. madagassicus*, *C. ashby* and *C.* sp.

Characters	*crosslandi*	*madagassicus*	*ashbyi*	sp. (Lavanono)
length max (mm)	25	21		27
valve i – radial ribs	13 (11 + 2)	11		11–12
valve i – radial ribs split	yes			no
int.valves – longitudinal ribs	18–20*	15	26	23–27
valve viii – radial ribs	18			10–14
dorsal scales – dimensions (μm)	220×160	250		228×145
dorsal scales – riblets	14–16	20		12–15
ventral scales – dimensions (μm)	70×12			85–100×18–25
* 12 in Sykes's description				

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TABLE 2
Length and number of radial ribs of valves i, iv and viii of *Callistochiton ashbyi* specimens.

Specimen	Length	Ribs (i)	Ribs (iv)	Ribs (viii)
1	23.6	11	27	13
2	23.3	11	26	12 (+2)
3	19.5	11	25	12
4	21.8	11	23	13
5	15	11	25	11
6	18.5	11	25	13
7	15.8	11	26	11 (+2)
8	11.8	12	26	10
9	15.4	12	25	14
10	11.7	11	25	13
11	15.2	11	23	9
12	12.5	11	27	10 (+1)
13	14.3	11	24	10 (+1)
14	14.5	12	23	12
15	10.8	14	27	10
16	11	12	26	12 (+1)
17	16.6	11	22	12
18	13.5	10	25	11 (+1)
19	27	12	26	11 (+1)
20	21.2	11	23	10

very significant collection. Table 2 shows number of radial ribs of valves i and viii and number of longitudinal ribs of valve iv compared to specimen length of all specimens of *C. ashbyi* from Lavanono. It is obvious that these are consistent characters, and that the differences shown in Table 1 are significant.

Leloup (1981) identified five specimens from Tuléar, collected by P. Galenon, as *Chiton ashbyi*, which is the only other record of this species.

C. barnardi and *C. rotondus* are different species, not comparable with the Lavanono material (Kaas & Van Belle 1994; Schwabe 2004; Dell'Angelo *et al*. 2010*b*).

Type material: Holotype: SAMC-A9337, an intermediate valve (Fig. 4F).

Type locality: South Africa, off Cape Infanta, 83 m, collected by R.S. *Pieter Faure*, 10 July 1900.

Material examined: Lavanono (Madagascar): 20 specimens (GP, BD, MZB).

Distribution: South Africa and Madagascar.

Family Chaetopleuridae Plate, 1899
Genus *Chaetopleura* Shuttleworth, 1853

Chaetopleura: Shuttleworth 1853: 190. Type species: *Chiton peruvianus* Lamarck, 1819, by subsequent designation (Dall 1879: 296).

For synonymy, see Kaas & Van Belle (1987).

Distribution: Worldwide, but most species occur in the tropical and subtropical regions of Africa, South and Central America. Oligocene – Recent.

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Chaetopleura chelazziana Ferreira, 1983

Fig. 4H

Chaetopleura chelazziana: Ferreira 1983: 254, figs 3–10; Dekker & Ceuninck van Capelle 1994: 134; Dekker & Orlin 2000: 7; Slieker 2000: 46, pl. 11, fig. 6.
Chaetopleura (*C.*) *chelazziana*: Kaas & Van Belle 1987: 93, fig. 41.
Dinoplax fossus (non Sykes, 1899): Kaas 1979: 861 (*fide* Kaas & Van Belle 1987: 95).

Comparison and remarks: The examined specimens fully agree with descriptions and figures provided by Ferreira (1983) and Kaas & Van Belle (1987). This is the first report of the species from Madagascar.

Type material: Holotype MZUF 4096 (Museo di Zoologia Università di Firenze). Paratypes: MZUF 4097 (1 specimen), CASC 031757 (1 specimen).

Type locality: Somalia, Gesira, 01°58'N:45°10'E, in the intertidal zone.

Material examined: MADAGASCAR: Lavanono, 25 specimens (GP, BD), from 26.5 to 69 mm long (figured specimen 69 mm long).

Distribution: The eastern coast of Africa, from 2°N (Gesira, Somalia), to 22°S (Inhambane Province, Mozambique), and Madagascar.

Suborder Acanthochitonina Bergenhayn, 1930
Family Cryptoplacidae H. & A. Adams, 1858
Genus *Cryptoplax* de Blainville, 1818

Cryptoplax: de Blainville 1818: 124. Type species: *Chiton larvaeformis* de Blainville in Burrow, 1815, by subsequent designation (Gray 1821: 234).

For synonymy see Gowlett-Holmes (2001: 45).

Distribution: Tropical and subtropical waters of the Indo-Pacific. Paleogene – Recent.

Cryptoplax dupuisi Ashby, 1931

Figs 3Q–X, 4I–X

Cryptoplax dupuisi: Ashby 1931: 13, pl. 2, figs 14, 15; Leloup 1940: 19, text-figs 6, 7, pl. 3, fig. 2; Fischer-Piette & Franc 1960: 1783, fig. 1567; Kaas 1979: 876 (only for specimen 40 mm long from Conducia Bay); Ferreira 1983: 289; Kaas & Van Belle 1998: 64; Slieker 2000: 50, pl. 13, fig. 30; Dell'Angelo *et al*. 2004*b*: 60; Dinapoli 2004: 65.
Cryptoplax burrowi (*non* E.A. Smith 1884): Sykes 1907: 33 (*fide* Kaas 1979; Ferreira 1983).
Not *Cryptoplax dupuisi*: Kaas 1979: 876 (the specimens 31 mm long from Conducia Bay and 11 mm long from Umkomaas = *C. sykesi* Thiele, 1909).

Description:

Animal vermiform-cylindrical, maximum estimated length more than 80 mm, the largest (curled) measures 75×10 mm. Characterised by having first three valves in contact and ollowing valves with spaces in between. In some specimens also fourth valves seem in contact, but this depends on dissimilar stretching of girdle in dried specimens. Distance between valves vi and vii generally widest, and distance between valves v and vi wider than between other valves (iv–v and vii–viii), while distance between valves iii and iv is smallest. All specimens except two are deprived of dorsal girdle covering from anterior margin to posterior margin of valve iv, showing underlying, blackish skin. Colour of girdle buffy brown, valves darkish brown in periphery, more clearin central part.

Tegmentum of head valve semi-elliptical, anterior margin rounded, posteriorly straight (Fig. 4Q). Second valve of rhomboidal shape, more rounded in anterior part (Fig. 4R). Other intermediate valves (iii–vii, Figs 4S–W) elliptical in shape, more

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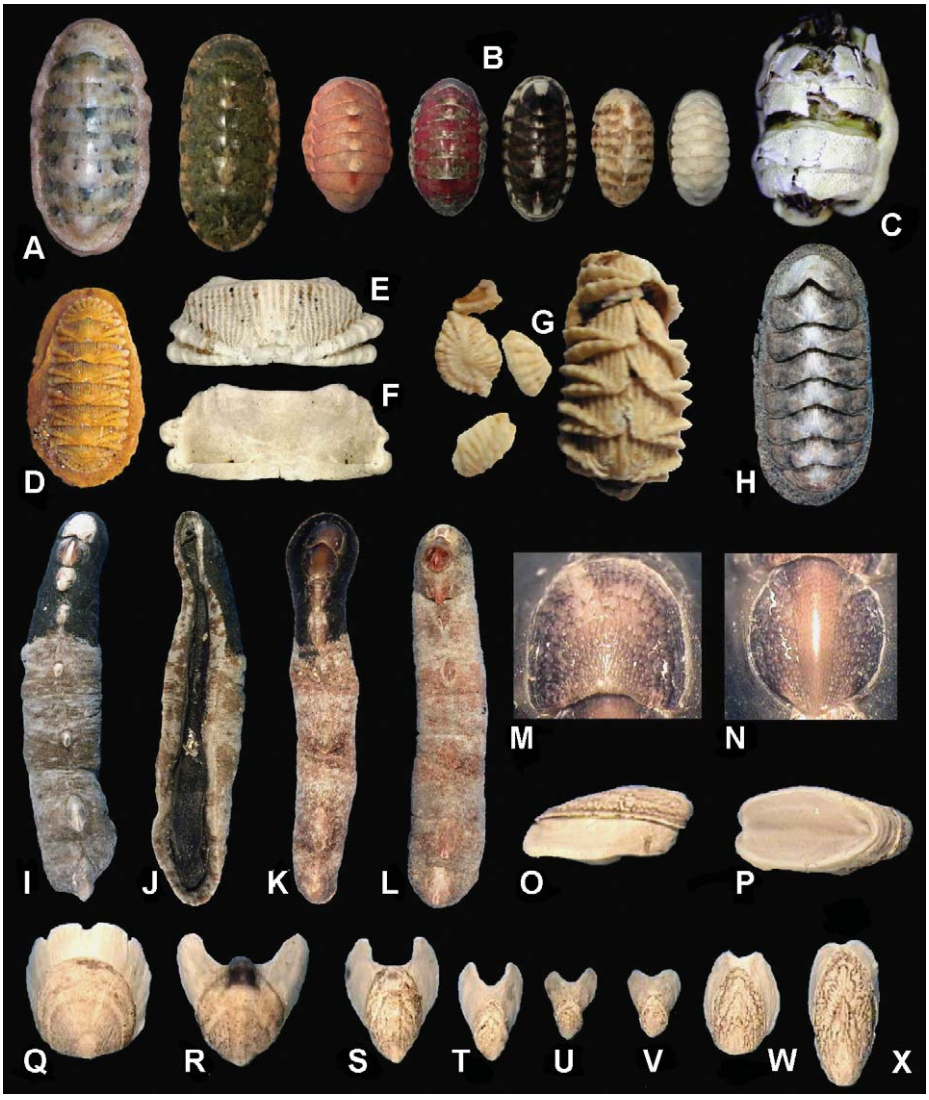


Fig. 4. (A, B) *Ischnochiton sirenkoi* sp. n., Lavanono, Madagascar: (A) holotype MZB 45693, 12.2 ×6.1 mm; (B) a lot of specimens showing colour variations, length, from left to right, respectively 17.7, 11.3, 11.2, 12, 10 and 9.5 mm; (C) *Ischnochiton sansibarensis* Thiele, 1909, holotype ZMB 102069, Zanzibar, *ca* 4 mm; (D–F) *Callistochiton ashbyi* (Barnard, 1963): (D) Lavanono, Madagascar, specimen n. 2 (Table 1), 23.3 mm; (E, F) holotype SAMC-A9337, an intermediate valve from Cape Infanta, South Africa, dorsal and ventral views, 9×3.3 mm; (G) *Callistochiton madagassicus* Thiele, 1909, holotype MNHN, Madagascar, 21×14 mm (from original description), some detached valves at left; (H) *Chaetopleura chelazziana* Ferreira, 1983, Lavanono, Madagascar, 47×31 mm; (I–X) *Cryptoplax dupuisi* Ashby, 1931, Lavanono, Madagascar: (I–K) specimens with the girdle deprived of dorsal spicules on the first four valves; (I, J) adult specimen, 51×12.5 mm; (K) the smaller specimen, 28.5×4 mm; (L) specimen with the girdle completely covered of dorsal spicules, 44×10 mm; (M, N) detail of sculpture of valves i–ii, *in situ*; (O, P) tail valve, lateral and ventral views, length 6.8 mm; (Q–X) valves i–viii (same scale), width (plates, without apophyses), from left to right, 4.4 mm (i), 3.9 mm (ii), 1.45 mm (iii), 2.65 mm (iv), 1.45 mm (v), 1.45 mm (vi), 2.4 mm (vii), 2.75 mm (viii).

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or less elongated, jugal area narrow and complete on all surface only in valves ii-iv, gradually reduced starting from apex in other valves. Tail valve elliptical, with posterior, backward-directed mucro, postmucronal area steep and almost straight (Figs 4O, 4P, 4X). Relative size of the valves is represented in Figs 4Q–X; for a specimen of a length of about 50 mm, valves v–vi are smallest. Tegmentum in uneroded specimens has elongate granules arranged in radial ribs in head valve, fused together towards sides (Fig. 4M). In intermediate valves, granules more rounded, less elongated, irregularly arranged, giving an impression of radial or longitudinal ribs starting from apex, more larger and irregular towards anterior valve margin, arranged following growth marks, jugal area smooth (Fig. 4N). Antemucronal area of tail valve sculptured like intermediate valves. Growth marks present on all valves.

Articulamentum white, strongly developed, forming large insertion plates. Intermediate and tail valves with large triangular apophyses, which always form a jugal lamina (Fig. 4P), except in valves ii and iii. Slit rays not present.

Perinotum wide, appears velvety without tuft pores, dorsally covered by dense, almost straight, conical spicules, *ca* 156×46 µm at base, generally deeply embedded in thick cuticle, sculptured longitudinally with 8 or 9 striae (Fig. 3S). Dorsal spicules do not wholly cover girdle surface, but only from posterior margin of valve iv, showing underlying, blackish skin in dorsal girdle corresponding to first four valves. Marginal fringe shows smooth, obtusely pointed, straight spicules of *ca* 200–235×55–60 µm (Fig. 3T). Ventrally, short, straight, elongate spicules, smooth or with some faint sign of dorsal ribs, *ca* 45–60×19–23 µm corresponding to girdle area with first four valves (Fig. 3U), tending to be more elongate, *ca* 45–88×19–23 µm corresponding to girdle area with valves v–viii (Fig. 3V). Marginal and ventral spicules wholly cover girdle.

Radula (Fig. 3W) with a short, rectangular, central tooth, with projecting horse-shoe but blade like; first lateral tooth wing-shaped and slightly curved, with rounded surface in upper part; second lateral tooth with broadly rectangular head, with three obtusely pointed, large denticles, almost equal-sized, outer one slightly shorter than others (Fig. 3X).

Comparison and remarks: This species was described from two specimens received by Ashby from P. Dupuis, collected in Madagascar (dimension of holotype 47×14 mm), but without precise locality. Leloup (1940) found three specimens in the collection of the Brussels Museum (45×11 mm, 32×9 mm and 11×3.5 mm), belonging to the original lot, and with the locality indicated, "Baie de Manafiafi, N. de Fort Dauphin". Kaas (1979) reported three other specimens, two from Mozambique (Conducia Bay, 40×11.5 mm and 31×7 mm) and one from KwaZulu-Natal (Umkomaas, a juvenile curled specimen of length *ca* 11 mm).

Leloup (1940) observed that the three specimens studied lack the girdle covering from the anterior margin to the posterior margin of valve iv, showing the underlying, blackish skin. The same can be assumed for the two original specimens described by Ashby, from the original figures (Ashby 1931, pl. 2, figs 14, 15) and by the girdle colour reported in the description ("buffy brown, the anterior portion as far as valve 4 blackish brown"). The same is reported by Kaas for the larger of the two Mozambique specimens, while the other from Mozambique and the specimen from KwaZulu-Natal have a wholly spiculose girdle.

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All the 51 specimens studied from Lavanono have the girdle lacking the dorsal spicules corresponding to the first four valves (Figs 4I, 4J), except the only specimen preserved in alchol (*ca* 35×8 mm, curled) and two dried specimens, 44×10 (Fig. 4L), and 45×9 mm, respectively. The absence of dorsal girdle spicules corresponding to the first four valves seem therefore the normal condition for this species, as already reported by Leloup (1940: 24): "Il est assez malaise d'expliquer ce dépouillement, certainement artificial, chez «tous» les specimens connus à l'heure actuelle". The two specimens reported by Kaas from Mozambique and KwaZulu-Natal as wholly spiculose with all the valves connected are probably not this species. All the specimens from Lavanono have the first three valves in contact and the following valves with spaces in between, and this is true for the specimens studied by Ashby and by Leloup. The smaller specimen from Lavanono measures 28.5×4 mm, comparable with the Kaas's Mozambique specimen (31×7 mm), and the valves iv–vii are disconnected (Fig. 4K). Also the smaller of the specimens reported by Leloup (11×3.5 mm), comparable with the specimen from KwaZulu-Natal (*ca* 11 mm) has the valves iv–viii disconnected (Leloup 1940: 21). Kaas did not illustrate his material, and we follow Ferreira (1983: 289), and consider the second specimen from Mozambique and the specimen from Natal reported by Kaas (1979) not belong to *Cryptoplax dupuisi*, but are probably to *C. sykesi* Thiele, 1909.

The lack of dorsal girdle spicules for the length of the first four valves is unique to this species, but at present we are not able to explain how or why this is present. Some *Cryptoplax* species live in a hole in corals, or in deep crevices in coralline rocks; Ang (1967: 431), states for *Cryptoplax planus* Ang, 1967 "They … are very difficult to collect because they occupy very deep crevices with very narrow openings which are just wide enough for them to get in and out", and Strack (1998: 37, fig. 17) figured a *C. planus* crawling from its burrow, only the anterior body emerges (mainly at night). They appear to eat coralline algae around the hole (Littler *et al*. 1995; Littler & Littler 1999). Rubbing the anterior part of the chiton dorsal girdle on rocks could cause the loss of the dorsal girdle spicules. However other species have the same habitat and do not show such damage to the girdle (e.g. *Cryptoplax larvaeformis*, as reported in Littler & Littler 1999). Also, this does not explain why only dorsal girdle spicules are missing, and not the marginal and ventral ones.

In conclusion, we do not have an explanation for the loss of dorsal girdle spicules around the first four valves in *Cryptoplax dupuisi.* The specimens from Lavanono were found under middle-size stones in small sandy pools among the rocks, at a depth of 20–50 cm, so even the "rubbing around the hole" theory does not apply here. The only other record of a chiton with "smooth" dorsal girdle is *Acanthochitona fascicularis* (L., 1767) from Italy, seen by Dell'Angelo *et al*. (2004*a*).

The Lavanono specimens agree with descriptions and figures of *C. dupuisi* in Ashby (1931) and Leloup (1940). Some differences are noticed in the girdle's formation measurements, compared with those reported by Leloup (drawings in 1/175 scale), generally higher than those measured in the studied material: 270–285 µm *vs* 156×46 µm for dorsal spicules in the Lavanono specimens, 450–600×34–45 µm vs 200–235×55–60 µm for marginal spicules, and 115–140×22 µm *vs* 45–88×19–23 µm for ventral ones. We consider that these differences in the girdle's measurements may be attributed to a low accuracy in Leloup's drawings. The sculpture of the valves is variable, related to the size of the animals, and tends to be more eroded and poorly defined in larger specimens,

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as already noted by Leloup (1940, fig. 6). For comparison, we illustrate the first two valves of the smaller specimen of the studied material (Figs 4M, 4N).

Two *Cryptoplax* species are known from Western Indian Ocean (Ferreira 1983; Dell' Angelo *et al*. 2004*b*), the present *C. dupuisi* and *C. sykesi* Thiele, 1909 (from northern Red Sea to South Africa, Socotra, Madagascar, Réunion, Maldives and Mauritius). A third species, *C. burrowi* (E.A. Smith, 1884) has been reported from the Maldive Islands (Dell'Angelo *et al*. 2010*a*). Kaas (1979) attributed to *C. dupuisi* specimens of *Cryptoplax* from East Africa identified at first by Sykes (1900, 1907) as *C. striata* (Lamarck, 1819), a species originally described from Australian waters, but this cannot be confirmed, as already noted by Thiele (1909) and Ferreira (1983), who proposed the name *C. sykesi* for Sykes's specimens.

Dinapoli (2004) reported two specimens (12 and 15 mm long) of a *Cryptoplax* sp. from Socotra Island, comparing them with *C. sykesi* and *C. dupuisi*, but it is possible that the two specimens belong to a *Choneplax* species (E. Schwabe, pers. comm.).

Type material: Holotype: "in Ashby collection" (not in SAMA, *fide* Robert Hamilton-Bruce, pers. comm., June 15, 2010). Paratype: SAMC (not in Giles & Gosliner's Catalog, but present in the Museum's collection, *fide* Elizabeth Hoenson, pers. comm., May 28, 2010).

Type locality: Madagascar, without precise locality (Baie de Manafiafi, N. de Fort Dauphin, *fide* Kaas 1979: 877).

Material examined: MADAGASCAR: Lavanono, 51 specimens, 50 dried and badly preserved, from 28.5×4 to 75×10 mm, one in alcohol (*ca* 35×8 mm, strongly curled) (GP, BD, MZB).

Distribution: Mozambique and Madagascar.

DISCUSSION

Despite the classical catalogues published by Lamy (1909*a*, *b*), Odhner (1919) and Dautzenberg (1923, 1929, 1932) and the numerous more recent contributions (e.g. Legendre 1965; Vicente 1966; Mars *et al*. 1972; Brygoo & Brygoo 1978; Cosel & Blöcher 1976; Leloup 1981; Bouchet 1999; Houart & Rosado 2008; Kaas 1986; Bonfitto & Sabelli 2001; Schwabe 2004; Dell'Angelo *et al*. 2004*b*, 2010*b*) the knowledge of the malacofauna of Madagascar, and its chiton fauna in particular, is still far from complete and needs further investigation. On this basis, the chitons from Lavanono allow us to increase our knowledge of Madagascar chitons.

Among the collected specimens, we have considered the 124 living ones belonging to the species reported in Table 3.

Other specimens were found but some of them are not considered in the present work as they belong to well-known species from the Madagascar and East African coasts (i.e. *Stenoplax* (*Stenoradsia*) *madagassica* (Thiele, 1917), *Lucilina carnosa* (Kaas, 1979)

TABLE 3

Total number of living specimens examined in this study.

Species	Specimens
Ischnochiton sirenkoi **sp. n.**	28
Callistochiton ashbyi	20
Chaetopleura chelazziana	25
Cryptoplax dupuisi	51
Total	124

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and *Acanthopleura brevispinosa* (Sowerby, 1840)), while other species need further studies, and will be reported on later.

The new species *Ischnochiton sirenkoi* increases the number of *Ischnochiton* species known from the area, while finding the specimens belonging to rare and poorly known species from the Indian Ocean allows us to clarify some taxonomic relationships and to extend to Madagascar the distribution of the species discussed above.

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