Journal of FISH BIOLOGY

fsbi An International Society for Fish Biology

Journal of Fish Biology (2017) **91**, 587–602
doi:10.1111/jfb.13371, available online at wileyonlinelibrary.com

Redescription and sexual dimorphism of Andaman leg-skate *Cruriraja andamanica* (Chondrichthyes: Rajiformes) with comments on the zoogeography of the genus *Cruriraja*

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(Received 22 February 2016, Accepted 31 May 2017)

This paper redescribes sexually dimorphic *Cruriraja andamanica* based on five juvenile (four males, one female) and four adult specimens (three males, one female) collected from Andaman waters. Morphometric comparison of the present specimens with a female specimen collected off the coast of Tanzania reveals considerable dissimilarities between them. These findings, along with the wide geographical distance between collection locations, support a need for revision of the Tanzanian specimen, which, in all probability, represents a new species in the genus. The paper also addresses zoogeography of genus *Cruriraja* across the world's oceans and provides a revised key to the species.

Key words: *Cruriraja andamanica*; leg-skates; redescription; sexual dimorphism; zoogeography.

INTRODUCTION

The skate genus *Cruriraja* Bigelow & Schroeder 1948 belongs to the family Anacanthobatidae in the order Rajiformes (Ebert & Compagno, 2007), which comprises the leg-skates. The generic name *Cruriraja* refers to the anterior crurae of the pelvic fins which is completely notched so that the anterior portion is entirely separated from the ventral surface of the disc, with the pelvic fins resembling a pair of legs (Bigelow & Schroeder, 1953). Skates, like all other chondrichthyan fishes, exhibit sexual dimorphism primarily in the structure of their pelvic fins. In males, the pelvic fins are modified into copulatory organs known as claspers. In addition to these claspers, mature males have alar thorns on the dorsal edges of their disc, which help them grasp the females during copulation (Ishiyama, 1958; Tricas, 1980; Braccini & Chiaramonte, 2002). Skates also display sexual dimorphism in several features, such as alar thorns, relative body length, body mass, age of sexual maturity and diet (Ishiyama, 1958; Jardas, 1975; Braccini & Chiaramonte, 2002; Gedamke *et al.,* 2005; Ruocco *et al.,* 2006;

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Scenna *et al.,* 2006; Orlov & Cotton, 2011; Martinez *et al.,* 2016). Mature females and males of several species of skates show differences in tooth shape; females possessing plate-like teeth with a subtriangular cusp, while in males teeth are sharp and conical (Ishiyama, 1958; McEachran, 1977; McCourt & Kerstitch, 1980; Kajiura & Tricas, 1996).

Feduccia & Slaughter (1974) examined the ranges of sexual dimorphism in the tooth structure among skates (Rajidae) and discussed its potential role in differential niche utilization. Their study indicated that most sexually dimorphic species tend to occur at greatest depths, where there are presumably fewer potential interspecific competitors. McEachran (1977), however, refuted the hypothesis by Feduccia & Slaughter (1974). According to McEachran (1977), dimorphism in tooth structure of skates coincides with the attainment of sexual maturity, hence may possibly serve in reproductive behaviour rather than differential niche utilization. Analysis of dental dimorphism in the Atlantic stingray *Hypanus sabinus* (LeSueur 1824) by Kajiura & Tricas (1996) suggested that the sexual dimorphism in tooth structure could be some advantage for increased feeding efficiency and sexual selection in males to maximize mating success.

Eight valid species of *Cruriraja* are known, inhabiting continental and insular shelves and slopes of the north, central-western and south-eastern Atlantic Ocean and south-western and eastern Indian Ocean (Ebert & Compagno, 2007). The International Union for Conservation of Nature (IUCN) red list of threatened species has included Andaman leg-skate *Cruriraja andamanica* (Lloyd 1909) in the data deficient category due to its poor documentation (McCormack, 2009). The only information available on this species is from two immature specimens, which include the male holotype collected from the Andaman Sea at about 510 m depth and another female specimen collected from 274 to 457 m depth off Tanzania (Stehmann, 1976; McEachran & Fechhelm, 1982). Based on new adult specimens (male and female) collected from 601–622 m depth in the Andaman Sea, the present paper redescribes the poorly known *C. andamanica*, with a detailed illustration of its secondary sexual dimorphic features.

MATERIALS AND METHODS

Specimens of *C. andamanica* were obtained during three deep-sea exploratory trawl surveys (Cruise No. 280, 292 and 334) of the fishery oceanographic R.V. *Sagar Sampada* in the Andaman waters of Indian exclusive economic zone (EEZ). The specimens were collected using the high speed demersal trawl-crustacean version (HSDT-CV) operated at a speed of *c.* 5·6 km h^{-1} (*i.e.* 3 knots). The samples were preserved in 5% buffered formaldehyde solution and deposited with the referral centre at the Centre for Marine Living Resources and Ecology (CMLRE), Cochin, India. Abbreviations of museum collections following Fricke & Eschmeyer (2017). The materials were identified as *C. andamanica* by comparison to the holotype and following the original description and illustration. Morphometric measurements (Table I) were taken on the formaldehyde preserved specimens following Hubbs & Ishiyama (1968) and standardized with the disc width (W_D). Morphometric features of the new specimens were compared with that of the holotype and the only other known specimen of the species (McEachran & Fechhelm, 1982). Principal component analysis (PCA) was carried out on selected morphometric measurements (only included measurements, which are available for all specimens), standardized in $\%W_D$ followed by $\log_{10}$ transformation in order to analyse the correlation between samples. The holotype in the museum of the Zoological Survey of India (ZSI F1129/1) was already in three pieces when Stehmann (1976) examined it and made morphometric measurements. At present the holotype is not in a condition to take reliable morphometric measurements (Fig. 1). Hence, the measurements of the holotype made by Stehmann (1976) are used for a reliable comparison. Clasper

TABLE I. Morphometric measurements of *Cruriraja andamanica*

	Sample voucher details					
	CMLRE 2803807a	CMLRE 2929113a	CMLRE 2803807b1–3	CMLRE 2929113b; 334LII7A1a-c	Holotype ZSI F1129/1	ZMA 113·400
	Capture location					
	Great Nicobar Island	Great Nicobar Island	Great Nicobar Island	Great Nicobar Island	Andaman waters[a]	Tanzania[b]
	Adult female ($n=1$)	Immature female ($n=1$)	Adult males ($n=3$)	Immature males ($n=4$)	Immature male ($n=1$)	Immature female ($n=1$)
Morphometric measurements						
Total length (mm)	452	293	398–410	213–350	207	179
Disc width (mm)	240	153	200–215	110–189	109	100
As % disc width						
1 Total length	188·3	191·5	188·6–199	185·2–190·0	188·3	178·6
2 Disc length	81·7	85·6	82·6–87·5	80·0–82·6	80·0	75·0
3 Snout to maximum disc width	54·2	52·3	52·6–58·5	49·7–55·0	–	49·0
4 Pre-orbital length	19·5	20·4	18·7–20·4	19·3–20·4	19·0	18·9
5 Eye diameter	5·0	5·8	5·7–6·3	5·1–5·7	–	–
6 Orbit diameter	7·6	8·8	8·7–9·1	8·1–9·1	9·0	7·5
7 Inter-orbital space	5·6	5·8	6·4–7·5	5·4–7·5	6·8	5·9
8 Spiracle length	4·1	4·2	3·5–4·7	3·5–5·3	4·5	3·0
9 Distance between spiracles	11·3	12·2	11·2–12·1	10·5–12·3	12·2	11·3
10 Snout to cloaca	75·0	74·5	72·3–76·0	68·8–74·5	73·6	67·9
11 Distance cloaca to caudal-fin tip	114·6	114·4	115·0–121·0	111·1–116·4	114·7	110·7
12 Mouth width	12·1	13·1	12·3–13·5	9·6–12·5	10·9	10·2
13 Pre-oral length	22·6	23·7	22·7–23·3	21·7–26·5	26·4	22·7

TABLE I. Continued

	Sample voucher details					
	CMLRE 2803807a	CMLRE 2929113a	CMLRE 2803807b1–3	CMLRE 2929113b; 334LII7A1a-c	Holotype ZSI F1129/1	ZMA 113·400
	Capture location					
	Great Nicobar Island	Great Nicobar Island	Great Nicobar Island	Great Nicobar Island	Andaman waters[a]	Tanzania[b]
	Adult female ($n = 1$)	Immature female ($n = 1$)	Adult males ($n = 3$)	Immature males ($n = 4$)	Immature male ($n = 1$)	Immature female ($n = 1$)
14 Internarial space	10·8	10·5	10·2–11·8	9·5–10·7	11·9	10·2
15 Nasal curtain (lobe width)	3·0	3·1	2·6–3·1	2·6–3·7	–	–
16 Pre-nasal length	18·5	19·1	17·9–18·8	16·9–19·6	–	17·0
17 Width of first gill opening	2·5	2·9	2·9–3·7	2·9–3·7	1·3	1·3
18 Width of third gill opening	3·0	2·9	2·7–3·9	2·7–3·9	1·9	1·4
19 Width of fifth gill opening	2·5	2·1	2·2–2·9	2·2–2·8	2·3	1·1
20 Distance between first gill openings	26·0	26·8	24·7–26·6	25·0–26·6	27·4	20·5
21 Distance between fifth gill openings	13·8	13·5	12·9–13·8	12·2–13·8	13·6	10·0
22 First dorsal height	3·4	3·2	2·3–5·5	2·1–6·7	–	–
23 First dorsal base length	5·4	5·9	5·1–6·9	5·2–6·7	–	–
24 Second dorsal height	3·2	3·4	5·2–5·6	1·9–3·8	–	–
25 Second dorsal base length	4·8	5·6	5·1–5·6	4·9–5·7	–	–
26 Inter dorsal length	2·7	1·8	1·6–2·2	1·3–3·3	–	–
27 Width pelvic anterior lobe	3·2	3·7	2·9–3·6	2·9–3·8	–	–
28 Length pelvic anterior lobe	20·9	21·2	20·9–23·7	18·5–24·7	20·9	25·7

CMLRE, Centre for Marine Living Resources and Ecology, Cochin, India; ZMA, Zoological Museum Amsterdam; ZSI, Zoological Survey of India.

[a]Stehmann (1976).

[b]McEachran & Fechhelm (1982).

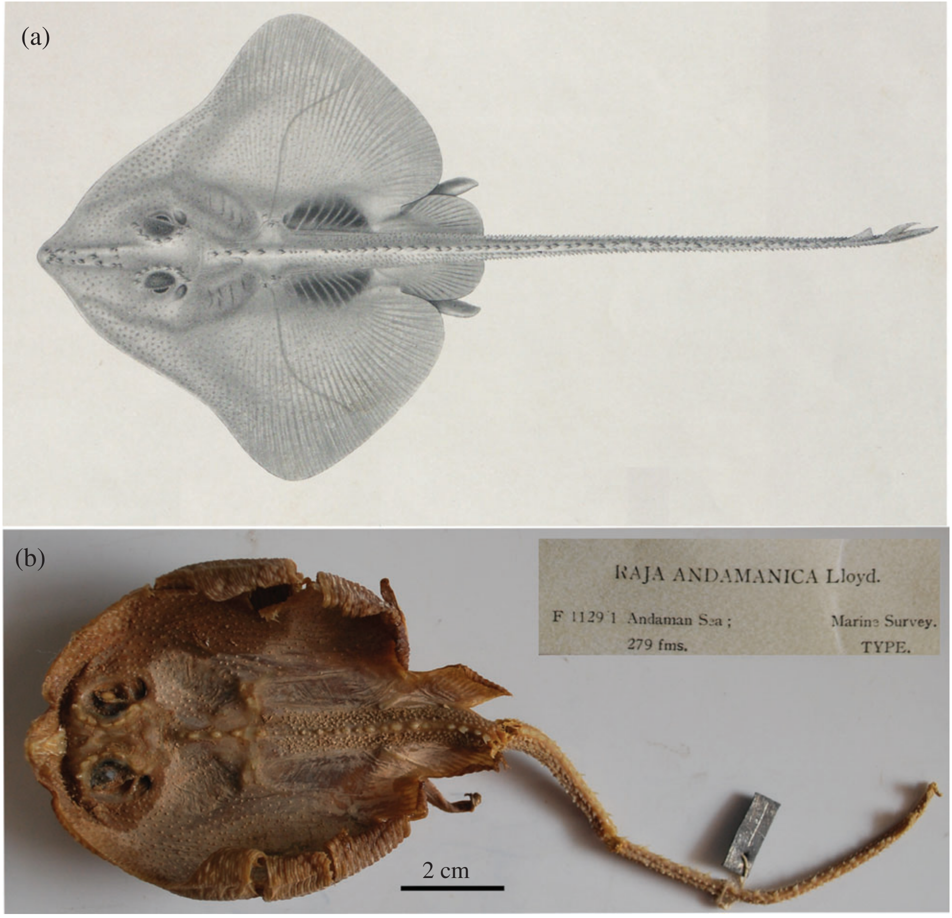

FIG. 1. (a) Original illustration of *Cruriraja andamanica* holotype: ZSI F1129/1, taken from Lloyd (1909*b*) and (b) the present status of the holotype. ZSI, Zoological Survey of India.

terminology follows Leible (1988). Systematic comparisons with congeners were also made to confirm species identity, based on original and other available taxonomic descriptions (von Bonde & Swart, 1923; Bigelow & Schroeder, 1948, 1958, 1962; Hulley, 1986; Carvalho *et al.,* 2006; Aschliman *et al.,* 2010; Ebert, 2014).

RESULTS

Specimens examined were of the order Rajiformes, family Anacanthobatidae von Bonde & Swart 1923 and genus *Cruriraja* Bigelow & Schroeder 1948 (Type species: *Cruriraja atlantis* Bigelow & Schroeder 1948).

CRURIRAJA ANDAMANICA (LLOYD 1909), (FIGS 1–7 AND TABLE 1)

Raia andamanica (Lloyd 1909*a*,*b*)

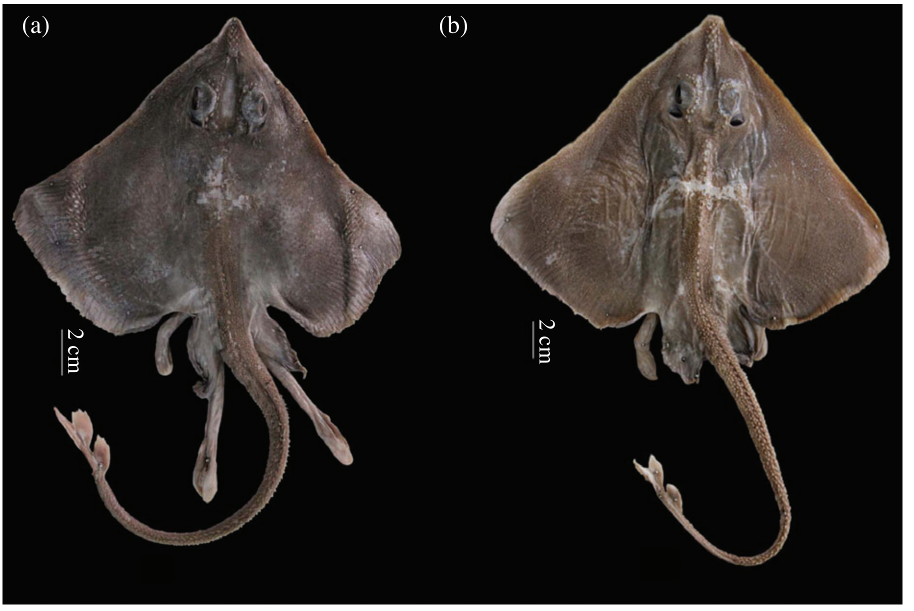

FIG. 2. Dorsal view of *Cruriraja andamanica* (a) CMLRE 2803807b1, 398 mm total length (L_T) adult male and (b) CMLRE 2803807a, 452 mm L_T, adult female. CMLRE, Centre for Marine Living Resources and Ecology, Cochin, India.

Type material

Holotype: ZSI F1129/1, immature male, 207 mm total length (L_T).

Type locality

Andaman Sea, station 332, 10° 21′ 0″ N; 92° 46′ 15″ E, 279 fathom (510 m), 12 April 1904.

Materials examined

ZSI F1129/1, one immature male, 207 mm L_T, Andaman Sea, Stn. 332, 510 m; CMLRE No. 2803807a, one adult female, 452 mm L_T, off Great Nicobar Island, 7° 52′ N; 93° 47′ E, 601 m, 24 September 2010; CMLRE No. 2803807b, three adult males 398–410 mm L_T, off Great Nicobar Island, 7° 52′ N; 93° 47′ E, depth 601 m, 24 September 2010; CMLRE No. 2929113a, one immature female, 293 mm L_T, off great Nicobar Island, 8° 21′ N; 93° 20′ E, depth 613 m, 14 November 2011; CMLRE No. 2929113b, one immature male, 266 mm L_T, off great Nicobar Island, 8° 21′ N; 93° 20′ E, depth 613 m, 14 November 2011; CMLRE No. 334LII7A1, three immature males, 213–350 mm L_T, off great Nicobar Island, 8° 23′ N; 93° 20′ E, depth 622 m, 29 January 2015.

Diagnosis

Cruriraja andamanica differs from its congeners with the following combination of characters: single series of enlarged thorns on mid-dorsal region, becoming multiple rows towards middle of tail; presence of rostral, nuchal and scapular thorns, small denticles on ventral side of tail; short inter-dorsal space, less than length of first dorsal base. Dorsal surface without blotches; caudal extremities and dorsal fins white.

Description

Morphometric measurements in proportion to disc width (Table I). Disc markedly quadrangular, maximum angle anterior to spiracles 80–90°, with greatest width posterior to horizontal midline; disc width 1·1–1·3 times its length. Anterior margins from snout to outer corners of pectorals markedly sinuous in adult males, nearly straight in adult female, with lateral corners abruptly rounded (Fig. 2). Snout blunt and projecting slightly beyond anterior margin of the rostral appendix; pre-nasal snout length slightly shorter than the pre-orbital snout length (0·74–0·88 times), which is about one-quarter of disc length. Eye diameter approximately equal to inter-orbital space and relatively larger than spiracle length; 0·49–0·53 times inter-spiracle width. Spiracles oval in shape, with pseudo-branchial fold on its antero-medial border. Nostril (Fig. 3) sub-oval to circular; anterior nasal flap expanded slightly, its lateral margin forming a short semicircular tube. Posterior nasal curtain well developed, expanded postero-laterally, rounded distally; internarial distance 0·38–0·44 times the distance between first gill slits, 0·78–0·86 times of the distance between fifth gill slits.

Mouth broad (Fig. 3), 0·5–0·7 times as wide as pre-narial length; upper and lower jaws slightly arched and indented on either side of symphysis in adult males (not indented in immature specimens and adult female). Teeth of adult males strongly pointed, unicuspid, caniniform; posteriorly directed in middle of upper jaw; cusps much shorter and slightly oblique towards jaw angle; similar in lower jaw but with relatively shorter cusps; arranged in longitudinal rows; 50 rows in the upper jaw and 42 rows in the lower jaw. Teeth of adult female with oval bases, having low subtriangular cusps; arranged in definite longitudinal rows. Teeth of immature males and females with short, subtriangular cusps and similar patterns of arrangement as that of adult female.

Pelvic fin separated into two morphologically distinct lobes. Anterior lobe limb-like, slender and greatly elongated; distally spatulate, extending up to the level of posterior lobe. Lateral margin of posterior pelvic lobe convex, with rounded angles in immature specimens and adult female; straight in adult males. Its inner margin associated with the clasper in adult males, with a pointed free posterior tip. Mature clasper long and robust, 0·2 times L_T, 35–40% of its length connected to the inner margin of posterior pelvic lobe; without dermal denticles; apophyle extending into posterior margin of pelvic clasper insertion; glans expanded; composed of eperon, rhipidion, pseudorhiphidion, spike, sentinel, knob and shield having five or six denticles along its antero-lateral margin (Fig. 4).

Tail elongate, tapered and relatively slender; length about 1·5 times distance from snout tip to rear of cloaca. First dorsal fin height 0·4–1·0 times its base length; distance from first dorsal fin origin to tail tip 3·2–3·8 times its base length; second dorsal fin nearly equal to first in size, distance between dorsal fins about 0·2–0·5 times first dorsal fin base. Lateral fold moderately developed, originating after middle of tail; running below dorsal fins and terminating before distal extremity of tail. Caudal fin not conspicuous, present as a dorsal skin-fold in the extremity of the tail (Fig. 5).

Dorsal surface of disc closely packed with numerous denticles, except the dorsal surface of pelvic fin and posterior mid-dorsal region of the disc, where they are widely scattered. Entire lower surface of disc smooth, devoid of denticles. Ventral

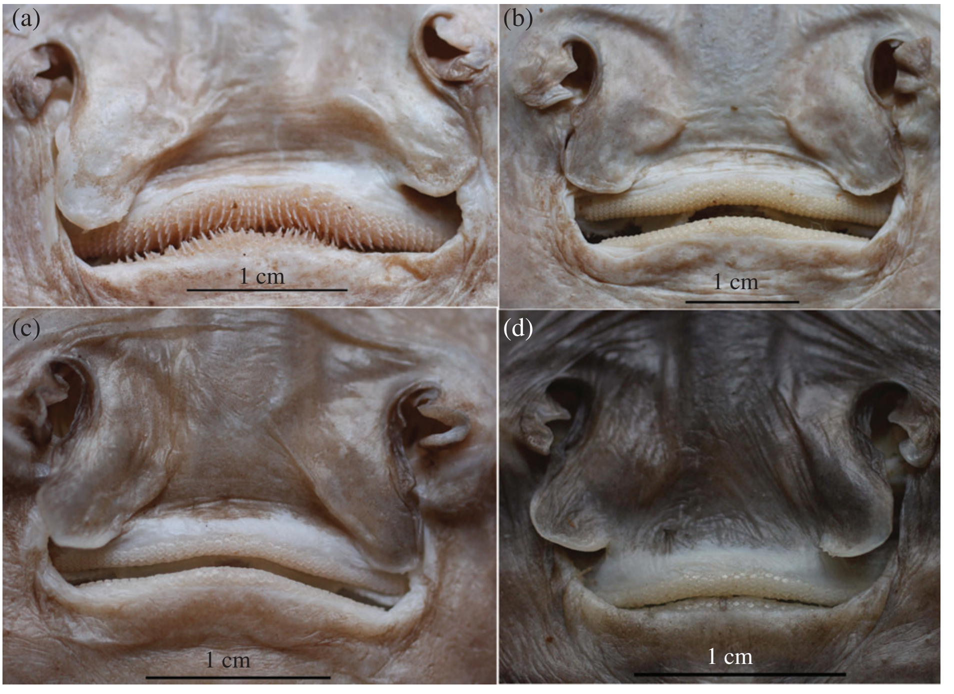

FIG. 3. Oro-nasal region and tooth pattern of *Cruriraja andamanica*. (a) Adult male, CMLRE 2803807b1, 398 mm total length (L_T); (b) adult female, CMLRE 2803807a, 452 mm L_T; (c) immature male, CMLRE 334LII7A1a, 213 mm L_T; (d) immature female, CMLRE No. 2929113a, 293 mm L_T. CMLRE, Centre for Marine Living Resources and Ecology, Cochin, India.

surface of tail bearing small denticles. Rostral cartilage with 10–15 wide-based, posteriorly directed spines on its anterior half. Supraorbital ridge bearing 11–15 large thorns arranged in semicircle, sometimes with one or two additional pre-orbital and post orbital thorns. Orbital thorns are scute-like and regularly spaced in females and immature specimens, but fewer orbital thorns in adult males. Alar thorns arranged in seven or eight rows; well developed in adult males; without barbs and obliquely directed relative to body axis. Two to seven posteriorly directed, broad-based nuchal thorns, few thorns missing in adult males and represented by scars. Two scapular thorns present, weak in adult specimens. Mid-dorsal row of thorns continuous with the median tail thorns in females, but discontinuous in immature and mature males. Median tail thorns (Fig. 6) extending as a single series of large spines up to anterior half of the tail, thereafter becoming less regular and arranged in two rows. Lateral tail thorns strong in female, weak in males. Two to three thorns present between dorsal fins.

Colour

Disc dorsally slate-grey in life, lacking blotches; ventrally light grey; snout, tail-tip including second dorsal fin and distal portion of first dorsal fin white. Colour camel-brown in preservation.

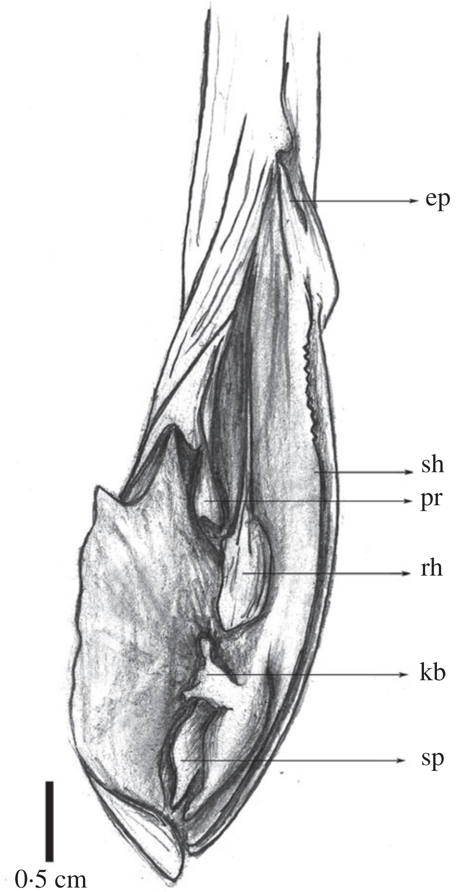

FIG. 4. Right clasper of *Cruriraja andamanica* CMLRE 2803807b1, lateral view partially expanded to show components. Ep: eperon; sh: shield; pr: pseudorhipidon; rh: rhipidion; kb: knob; sp: spike. CMLRE, Centre for Marine Living Resources and Ecology, Cochin, India.

Distribution

Known only off Great Nicobar Island (510–622 m), Andaman Sea. Identity of the specimen collected from off Tanzania needs verification, as discussed below.

Comparisons

Cruriraja andamanica differs from its congeners in several characters: the presence of a single series of enlarged thorns on the mid-dorsal region [multiple series in *Cruriraja parcomaculata* (von Bonde & Swart 1923) and *Cruriraja hulleyi* Aschliman, Ebert & Compagno 2010]; single series of enlarged thorns originating from the mid-dorsal region and becoming less regular and arranged in multiple rows upon reaching the middle region of the tail (regular and in a single series throughout the length in *Cruriraja rugosa* Bigelow & Schroeder 1958); presence of rostral thorns [absent in *Cruriraja durbanensis* (von Bonde & Swart 1923)]; presence of nuchal thorns (absent in *Cruriraja poeyi* Bigelow & Schroeder 1948); presence of small denticles on ventral side

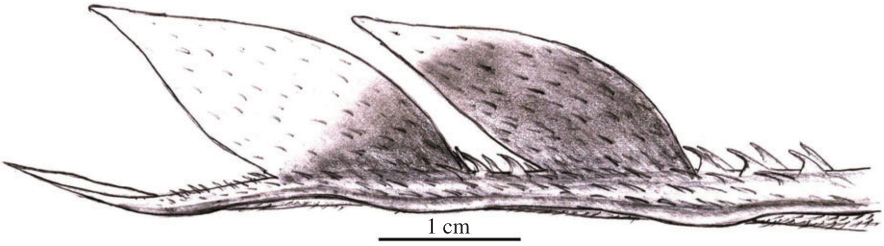

FIG. 5. Lateral right-side view of dorsal fins and caudal fin of *Cruriraja andamanica,* CMLRE 2803807b1, adult male, 398 mm total length. CMLRE, Centre for Marine Living Resources and Ecology, Cochin, India.

of the tail (absent in *Cruriraja cadenati* Bigelow & Schroeder 1962); and short gap between dorsal fins (at least 1·5 times the base of the first dorsal in *Cruriraja atlantis* Bigelow & Schroeder 1948). Other distinctive characters of *C. andamanica* are the presence of weak scapular thorns (absent in *C. rugosa* and *C. poeyi*); dorsal surface lacking blotches (large dark brown spots in *C. poeyi*; numerous small irregular brown spots in *C. cadenati*); rostral tip, caudal extremity and dorsal fins white in colour (black in *C. atlantis* and *C. rugosa*).

Remarks

Proportional measurements of male specimens in relation to W_D agree with that of the immature male holotype. Some characters, however, such as first branchial slit width (2·5–3·7% W_D in CMLRE specimens *v.* 1·4% in holotype) and third branchial slit width (2·7–3·9% W_D *v.* 1·9%) and space between first branchial slits (24·7–26·8% W_D *v.* 27·4%) show minor differences. Comparison of morphometric measurements between sexes (Table I) show minor variations with respect to the eye diameter, orbit diameter, first branchial slit width and space between first branchial slits.

The immature female specimen collected off Tanzania, identified as *C. andamanica* by McEachran & Fechhelm (1982), is well separated (falls outside the 90% confidence ellipse area) from the immature male holotype as well as present specimens in the ordination of principle components with respect to its morphometric vectors (Fig. 7). McEachran & Fechhelm (1982) themselves noted that the Tanzanian specimen differs from the holotype only in possessing a shorter spiracle and having a greater distance between the first and fifth gill slits. Based on detailed comparisons, it is found that the Tanzanian specimen has a shorter disc length, snout to maximum disc width, orbit diameter, mouth width, inter narial space, pre-oral length, pre-nasal length, branchial slit width, space between branchial slits, cloaca to tail distance and snout to cloacal distance (in proportion to disc width) and a large disc width with respect to total length (Table I). This discrepancy may have arisen due to the fact that McEachran & Fechhelm (1982) considered L_T, rather than disc width (W_D), to derive relative proportions. Comparison of the morphometric features with a relatively larger morphometric feature (L_T) could have resulted in insignificant differences from the holotype of *C. andamanica*. For example, while a comparison of disc length of the holotype and the Tanzanian specimen in percent of L_T (42·5 and 42·0%, respectively) minimizes the difference, the same in percent of W_D results in a much larger difference (80·0 and 75·0%, respectively). Thus, the placement of the Tanzanian specimen in *C. andamanica* should be carefully re-examined, as it may represent an undescribed species of *Cruriraja*.

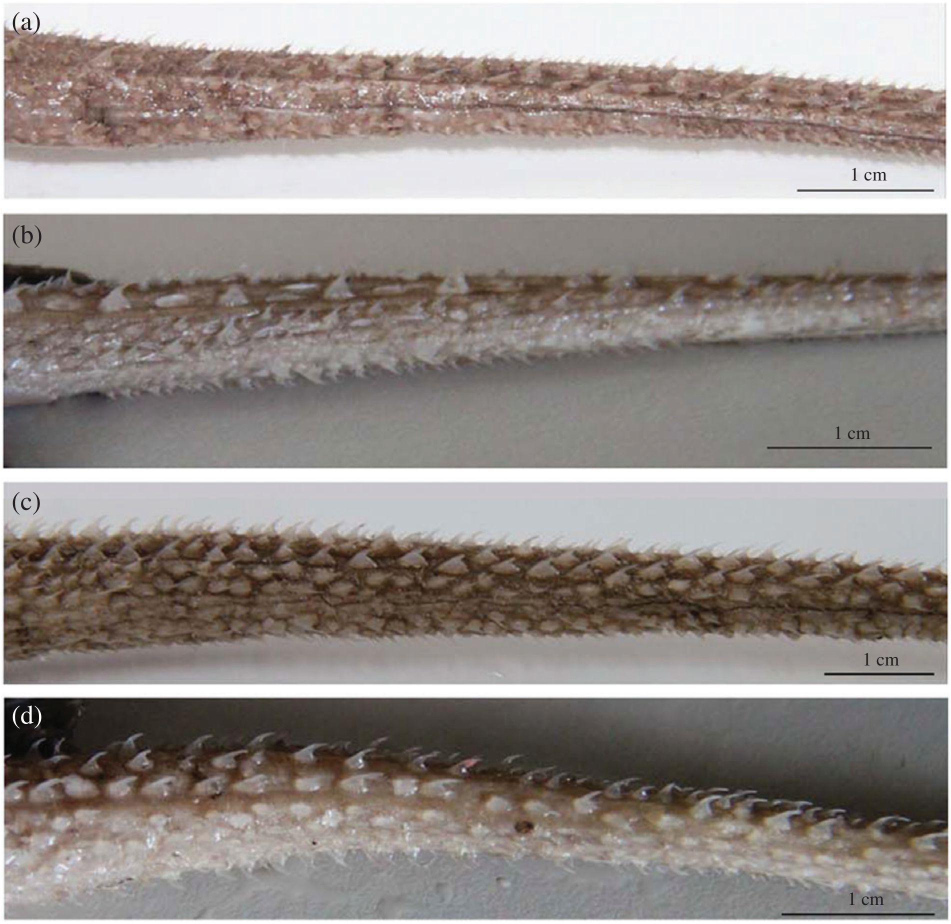

FIG. 6. Mid-tail region of *Cruriraja andamanica* (a) adult male, (b) immature male, (c) adult female and (d) immature female.

REVISED KEY TO THE SPECIES OF GENUS *CRURIRAJA*

Modified after Bigelow & Schroeder (1962) and Aschliman *et al.* (2010)

1a. Mid-dorsal region of the disc with a single row of enlarged thorns 2
1b. Mid-dorsal region of the disc with multiple rows of enlarged thorns 7
2a. Single row of enlarged thorns on the mid-dorsal region of the disc is regular and continues as a single row throughout the length of tail. . . . . *C. rugosa* (Central Atlantic to South western Atlantic Ocean)
2b. Single row of enlarged thorns on the mid-dorsal region of the disc; becoming less regular and arranged in multiple rows on reaching middle portion tail 3
3a. Dorsal fins placed well separated on the tail, inter-dorsal space more than at least 1·5 times the 1st dorsal fin base length . . . . *C. atlantis* (western Atlantic Ocean)
3b. Dorsal fins situated close together distally on the tail; inter-dorsal space less than first dorsal base length 4

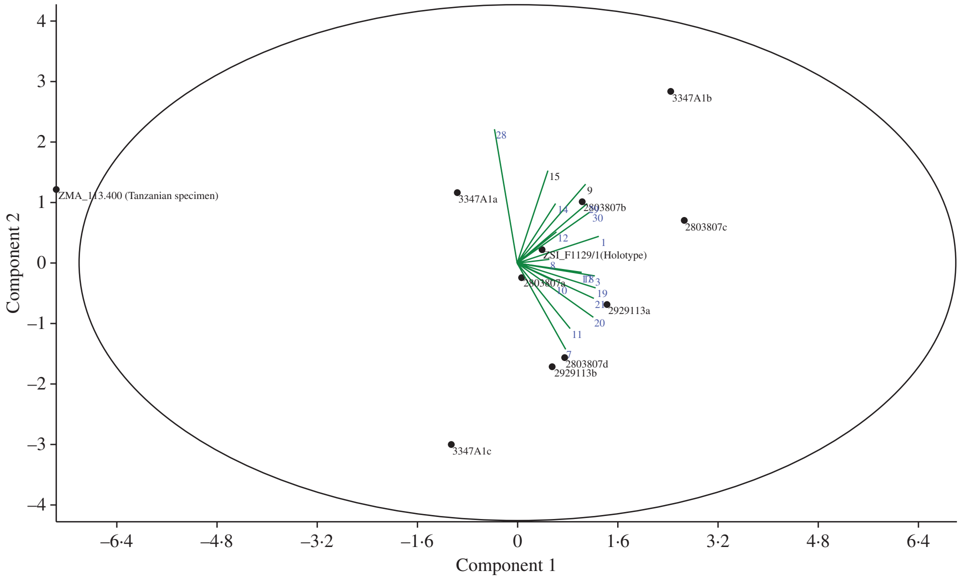

FIG. 7. Principal component analysis (PCA) scatter plot showing ordination of 11 specimens of *Cruriraja andamanica* (including holotype, Tanzanian specimen and nine specimens from the present study) against selected 18 morphometric measurement vectors corresponding to the characteristics numbered in Table I.

4a. Nuchal thorns and scapular thorns absent . . . . . . *C. poeyi* (western Atlantic Ocean)
4b. Nuchal thorns and scapular thorns present 5
5a. Rostral thorns absent. . . . . *C. durbanensis* (eastern Atlantic Ocean)
5b. Rostral thorns present 6
6a. Dorsal disc with dark brown blotches, lower surface of the tail without denticles . . . . *C. cadenati* (western Atlantic Ocean)
6b. Dorsal disc without any blotches, lower surface of the tail with denticles. . . . . *C. andamanica* (eastern Indian Ocean)
7a. Thorns of mid-dorsal disc in a continuous row over anterior half of abdominal region; inter dorsal space usually less than half of first dorsal fin base. . . . . *C. parcomaculata* (western Indian Ocean)
7b. Thorns absent on mid-dorsal disc above anterior half of abdominal region; inter dorsal space usually greater than half first dorsal fin base. . . . . *C. hulleyi* (eastern Atlantic Ocean)

DISCUSSION

ZOOGEOGRAPHY OF THE GENUS

All members of genus *Cruriraja* inhabit continental and insular shelves and slopes of the world's oceans. Based on the distribution of the eight species of *Cruriraja*, four discreet zoogeographic regions can be delineated (Fig. 8), namely the north-western, central and south-eastern Atlantic Ocean, south-western and central-eastern Indian Ocean. Four species are recorded in the north-western and central Atlantic Ocean: *C.*

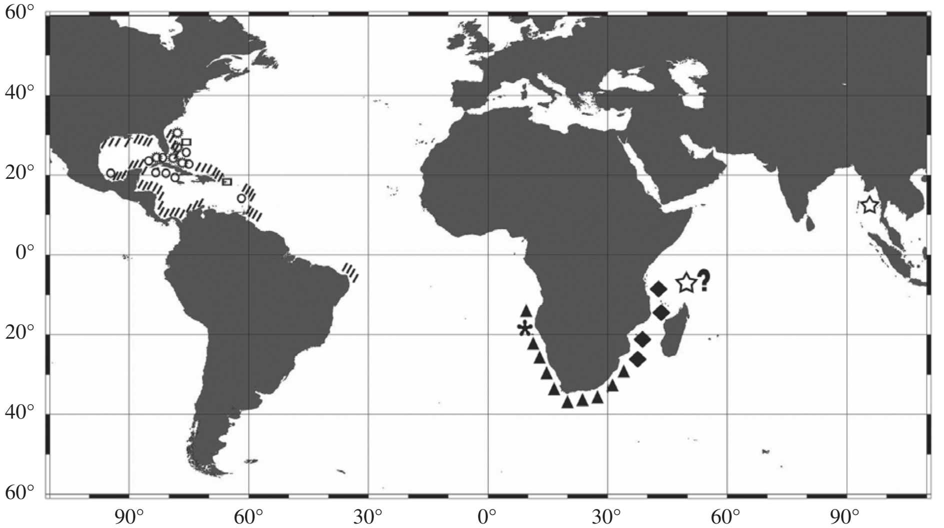

FIG. 8. Distribution of the genus *Cruriraja* in the world's oceans: ▨, *Cruriraja rugosa*; ✵, *Cruriraja atlantis*; ○, *Cruriraja poeyi*; □, *Cruriraja cadenati*; ◆, *Cruriraja parcomaculata*; ▲, *Cruriraja hulleyi*; ★, *Cruriraja durbanensis*; ☆, *Cruriraja andamanica*).

atlantis, *C. poeyi*, *C. cadenati* and *C. rugosa*. Among these, *C. atlantis*, *C. poeyi* and *C. cadenati* are restricted to the central part of the western Atlantic Ocean, whereas *C. rugosa* exhibits a wide distribution from the central to south-western Atlantic Ocean (Carvalho *et al.,* 2006). Two species, *C. hulleyi* and *C. durbanensis*, are known from the south-eastern Atlantic Ocean. The former has a wide distribution off of Namibia and around the Cape coast of South Africa (from Luderitz to Angola Bay and possibly East London) reaching up to the border of the western Indian Ocean (Aschliman *et al.,* 2010), while the latter is represented only by two specimens off Hondeklip Bay in South Africa (Compagno & Ebert, 2007). One species, *C. parcomaculata*, is known from off KwaZulu-Natal and Mozambique in the south-western Indian Ocean (Compagno & Ebert, 2007) and one species, *C. andamanica* is recorded from the Andaman waters in the central-eastern Indian Ocean region (Lloyd, 1909*a*). Though one specimen of *C. andamanica* was reported from off Tanzania, the identity of the specimen is doubtful and not considered in this study. It is interesting to note that there are no reports of the genus *Cruriraja* from the Pacific Ocean, despite the fact that the Rajiforms of the region are taxonomically well-studied. Examination of bathymetric ranges of the genus reveals that *C. cadenati* occupies deeper areas (457–896 m), whereas *C. hulleyi* and *C. parcomaculata* are recorded over a wide range at shallow to intermediate depths (39–520 and 65–680 m, respectively).

Carvalho *et al.* (2006) observed a high degree of endemism displayed by species of *Cruriraja*, except for *C. rugosa,* which is recorded in several regions of the western Atlantic and *C. andamanica,* which was reported both from the eastern (Andaman waters) and western (off Tanzania) Indian Ocean. The present work, however, has revealed that the Tanzanian specimen attributed to *C. andamanica* is not likely to be conspecific with the Andaman specimens. Further, the continental margins of the northern Indian Ocean (particularly within the Indian EEZ regions of the eastern

Arabian Sea, western Bay of Bengal and Andaman waters) have been subjected to much exploratory deep-sea surveys on-board R.V. *Sagar Sampada* since 1998 (418 bottom-trawl operations between 150–1500 m depth) and specimens of *C. andamanica* have been recorded only from the current locality, off the Nicobar Islands. This further underlines the high degree of endemism of species of *C. andamanica*.

SEXUAL DIMORPHISM IN TOOTH SHAPE OF *C. ANDAMANICA*

Sexual dimorphism is conspicuous in *C. andamanica*, with adult males being characterized with well-developed claspers, alar thorns, reduction in the number of enlarged thorns on the mid-dorsal region and most notably the differences in tooth shape compared with females. Sexual dimorphism in tooth structure and shape have been reported for other members of *Cruriraja* (Bigelow & Schroeder, 1953, 1962; Carvalho *et al.,* 2006; Aschliman *et al.,* 2010), with the females possessing small triangular-cusped teeth and males with prominent conical-cusped teeth. Feduccia & Slaughter (1974) attributed such changes in tooth structure as wear-induced, with both sexes having pointed teeth to begin with, but these being reduced to grinding buttons in females owing to regular use. In the present specimens of *C. andamanica*, it is found that all immature (male and female) specimen possess grinding-type teeth [Fig. 3(c), (d)] and that these are retained in adult females [Fig. 3(b)], while in males, they become modified (in length and shape) upon attaining sexual maturity [Fig. 3(a)], most probably under the influence of male sex hormones (Lutton & Callard, 2007). The present observations on the tooth structure of *C. andamanica* specimens clearly disagree with the wear-induced hypothesis in tooth dimorphism in skates put forward by Feduccia & Slaughter (1974) and agree with the findings of McEachran (1977).

The authors express sincere gratitude to M. Sudhakar, Director CMLRE for his support and encouragement. We also thank chief scientists, scientific participants, the captain and crew of R.V. *Sagar Sampada* cruises 280, 291 and 334. We acknowledge the constant support of P. Jasmin (ZSI), K. U. Abdul Jaleel and J. Jacob (CMLRE). Authors are thankful to the editors and anonymous reviewers, for their constructive suggestions and comments, which were very helpful in improving the manuscript. This is CMLRE contribution No. 80.

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