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Notoraja martinezi sp. nov., a new species of deepwater skate and the first record of the genus *Notoraja* Ishiyama, 1958 (Rajiformes: Arhynchobatidae) from the eastern Pacific Ocean

FRANCISCO J. CONCHA[1,2,7], DAVID A. EBERT[3,4,5] & DOUGLAS J. LONG[4,6]

[1]*Department of Ecology & Evolutionary Biology, University of Connecticut. 75 North Eagleville Road – Unit 3043 Storrs, CT, 06269, USA. E-mail: francisco.concha_toro@uconn.edu*
[2]*Facultad de Ciencias del Mar y de Recursos Naturales, Universidad de Valparaíso. Av. Borgoño 16344, Viña del Mar, Chile.*
[3]*Pacific Shark Research Center, Moss Landing Marine Laboratories, Moss Landing, CA 95039, USA.*
[4]*Department of Ichthyology, California Academy of Sciences, 55 Music Concourse Drive, San Francisco, CA. 94118, USA.*
[5]*South African Institute for Aquatic Biodiversity, Private Bag 1015, Grahamstown, 6140, South Africa. E-mail: debert@mlml.calstate.edu.*
[6]*Department of Biology, St. Mary's College, 1928 St. Mary's Road, Moraga, California 94575. E-mail: dlong@stmarys-ca.edu*
[7]*Corresponding author*

Abstract

A new arhynchobatid skate, *Notoraja martinezi*, **sp. nov.**, is described from four specimens collected from the eastern Central Pacific from Costa Rica to Ecuador and between depths of 1256–1472 m. The new species is placed in the genus *Notoraja* based on the long and flexible rostrum and its proportionally long tail with respect to total length. This species is distinct from its congeners in the Western Pacific by the straight margins of its rostrum, long anterior lobes of pelvic fins, and its abundant and very well developed caudal thorns.

Key words: Chondrichthyes, batoids, softnose skate, new species, eastern Pacific

Introduction

The soft nose skate genus *Notoraja* Ishiyama, 1958 (Rajiformes: Arhynchobatidae) was originally described as a subgenus of *Breviraja* Bigelow & Schroeder, 1948, but was later elevated by Stehmann (1989) to full generic status. The genus currently comprises 11 valid species, all occurring in the western Pacific and eastern Indian Oceans, including southern Australia (Ebert 2014). At present, no members of this genus are known from the western Indian Ocean or eastern Pacific. However, during a series of exploratory trawling surveys conducted by the Spanish research vessel *Miguel Oliver* in 2008 and 2010 off the Pacific coast of Central and northern South America, several skate specimens were collected that conform to *Notoraja*. Subsequent examination and morphological evaluation confirmed their placement in the genus, establishing a new record of this genus from the eastern Central Pacific, and representing a new species, described herein.

Material and methods

Examination of the holotype and three paratypes were measured in full, following morphometric techniques and terminology of other recent *Notoraja* species descriptions by Last *et al*. (2008) and Séret & Last (2009, 2012). Meristics, including vertebral counts from radiographs, were taken from the type specimens and compared to publish accounts of other known species within the genus (McEachran & Last 1994, 2008; Last & McEachran 2006; Séret & Last 2009, 2012). Tissue samples were taken from the three paratypes and sent to the College of Charleston for sequencing at the mitochondrial DNA NADH dehydrogenase subunit 2 (NADH2) locus that has

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been shown to be useful for distinguishing elasmobranch species (Naylor *et al*. 2012). Institutional abbreviations follow Sabaj Pérez (2014).

Notoraja Ishiyama, 1958

Type species: *Raja tobitukai* Hiyama, 1940, by original designation (also monotypic).

Notoraja martinezi, sp. nov.

Barbedwire-tailed skate; raya de púas
(Figures 1–7, Table 1)

Holotype. Specimen MEPN 18198, (Figs. 1; 2) 475 mm TL fresh, adult male, off Ecuador, eastern Central Pacific Ocean (0° 28' 39.14" S; 81° 7' 9.67" W), bottom trawl, 1256–1308 m, R/V *Miguel Oliver*, cruise "Ecuador 08", J. Martínez, 13 August 2008. Deposited in the Ichthyological Collection of Museo de Historia Natural Gustavo Orcés V., Escuela Politécnica Nacional. Quito, Ecuador.

Paratypes. Three specimens all collected during Miguel Oliver Pacific expedition 2010 by D. R. Robertson, R/V *Miguel Oliver*: USNM 422638, (Fig. 3) [tissue voucher number MOP–110513], 346 mm TL, female, Panama, 6˚ 54' 40" N, 81˚ 18' 11" W, collected between 1467–1472 m, Miguel Oliver Pacific expedition 2010, Station MOP11–28, 18 November 2010; USNM 421575, [tissue voucher number MOP–110737], 328 mm TL, female, Costa Rica, 9˚ 21' 32" N, 85˚ 26' 04" W, collected between 1414–1457 m, Miguel Oliver Pacific expedition 2010, Station MOP11–62, 25 November 2010; USNM 421352, [tissue voucher number MOP–110777], 243 mm TL, female, Central America, specific location and station not given, November 2010.

Diagnosis. A heart-shaped, medium-size species of *Notoraja*. Dark brownish dorsal and ventral surface; disc slightly wider 54.7 (51.7–55.2) %TL than long 51.6 (49.0–54.3) %TL. Dorsal head length 21.3 (18.9–20.4) %TL; interspiracular width 6.3 (6.6–7.6) %TL; internarial space 8.4 (6.6–7.9) %TL; preorbital length 14.9 (13.0–14.9) %TL, 4.4 (3.8–4.9) times orbit length and 3.0 (2.9–3.3) times distance between eyes (interorbital space); tail width at pelvic fin axil 1.5 (1.3–1.4) times its height; single, strong, hook-like, angled posteriorly preorbital thorn; disk with small, fine denticles randomly distributed, slightly more abundant on the sides of the caudal region; claspers long (cloacal length) 23.8% TL and slim; tail long and slender, covered with abundant strong, thin, non aligned and posteriorly angled thorns, which differs from all other described species of the genus; thin lateral tail folds merging at tail axil, thinner than tail width at any point and enlarged posteriorly; nasal lobes expanded, nasal curtain maximum width 8.4 (7.8–9.5) %TL; anterior pelvic-fin lobe longer than posterior 13.1 (16.2–16.8) %TL and 10.1 (7.8–9.8)% TL when straightened (shorter than posterior in natural position though); total pectoral-fin radials 65 (63–65); Monospondylus centra 25 (24–26); predorsal diplospondylous centra 58 (60–65); total predorsal centra 83 (85–91); caudal centra 20 (22-25) total centra 118 (123–128).

Description. Disc heart-shaped (Figs. 1–3), 0.6 (0.5–0.6) times as broad as long in holotype and paratypes; maximum angle in front of spiracles 66.2° (78.5–82.8°); longer snout in male; sexual dimorphism for anterior margin of disc, almost straight from tip of the rostrum to anterior margin of the first pair of gill slits in holotype (Fig. 4), while in paratypes, slightly convex from the tip of the snout to level of spiracle; then concave to maximum width of pectoral fins; posterior margin of disc broadly rounded, inner pectoral corner also rounded (Figs. 1; 3). Axis of greater width at 30% (26–29%) of disc length. Preorbital snout length 4.4 (3.8–4.9) times orbit length, 3.0 (2.9–3.3) times interorbital width; preoral snout length 1.8 (1.7–1.9) times internarial distance. Maximum orbit diameter 0.7 (0.7–0.8) times interorbital distance, 1.5 (1.7–2.0) times length of spiracle. Nasal curtain with a weak rounded process along lateral margin at the anterior margin of oro-nasal groove, posterior lobe of the nasal curtain broadly rounded and not fringed. Mouth width 1.0 (0.8–0.9) times maximum width of nasal curtain. Upper and lower jaws indented and arched in about 61° on either side of symphysis. Teeth with oval crown and less acute cusps in male holotype and slightly less acutely-pointed cusps in female paratypes; arranged in "vertical" rows in mature male holotype and in quincunx in females. Distance between first gill slits 1.5 (1.9–1.9) times as great as between nostrils; distance between fifth gill slits 1.1 (1.1–1.3) times as great as between nostrils.

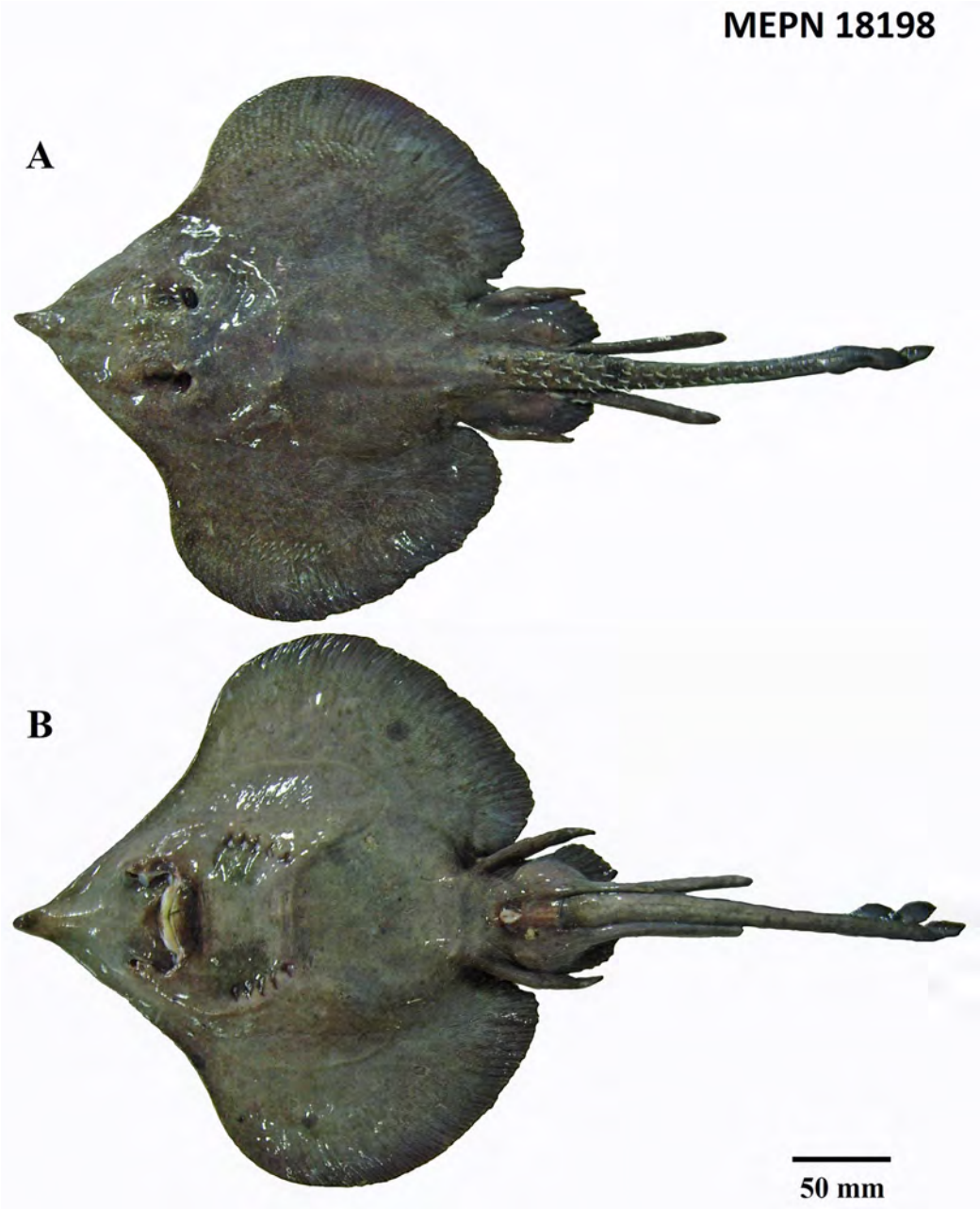

FIGURE 1. *Notoraja martinezi* **sp. nov.**, adult male holotype (MEPN 18198) photographed when collected: A. dorsal surface; B. ventral surface.

Pelvic fins deeply incised with lobes connected by radials and membranes forming a deep axil, finger-like slim anterior lobe, slightly longer than posterior lobe, with an acute (but not sharp) tip; posterior lobe with convex lateral margins, its posterior margin crenate due to extension of posterior radials. Tail long and slender, narrow at base, depressed over length, dorsally convex, ventrally flattened, and tapering gradually posteriorly, very slender toward tip; width at axils of pelvic fins 1.7 (1.7–2.0) times width at midlength of tail and 2.5 (3.3–4.0) times width at dorsal-fin origin respectively; tail length from rear of cloaca 1.1 (1.1–1.3) times distance from tip of snout to rear of cloaca; tail width 1.5 (1.3–1.4) times height at axils of pelvic fin and width at first dorsal-fin origin 1.5 (1.0–2.0) times height; lateral skin folds originating at pelvic fin axils, narrower than tail width, extending to distal end of tail and fusing with caudal fin. Dorsal fins of similar shape and size; rather short and moderately tall with evenly convex anterior margin, straight or slightly convex posterior margin, and a pointed or acutely rounded tip; generally separated by very short interspace, 0.8 (0.4–1.6) times dorsal-fin base length. Epichordal caudal-fin lobe developed, separated by narrow interspace from and distinctly longer than second dorsal-fin base; hypochordal

caudal lobe very narrow, fused with lateral fold, confluent with epichordal lobe. Adult male holotype and female paratypes largely free of dermal denticles except along anterolateral margins of pectoral fins; a short and thick preorbital thorn posteromedially oriented (Fig. 5). Ten alar thorns in two irregular rows in male holotype; posteromedially oriented, with oval base, oblique slightly curved crowns, exposed on integument; malar hooks patch absent. Tail prickly with numerous, posteriorly angled and large hook-like thorns and thornlets on its dorsal surface (Fig. 6); 13 medium thorns randomly aligned with oval bases, very small, first thorn posterior to free rear tip of pelvic fins; medium thorns smaller than lateral thorns; medium row and left lateral thorn rows merge towards end of tail with smaller medium row posteriorly becoming single row of smaller thorns; last 4 thorns are randomly aligned. Ventral surface of disc and tail totally naked, lacking thorns or thornlets. Claspers (Fig. 7) of adult male holotype long, very slender and not broadned from their origins to the bluntly pointed tips; with inner components slit, cleft, pseudorhipidion, projection, riphidion and spike. Clasper glans semicircular, dorsoventrally and laterally expanded. Distance from the posterior end of the cloaca to the tips of the clasper, 23.8% of total length.

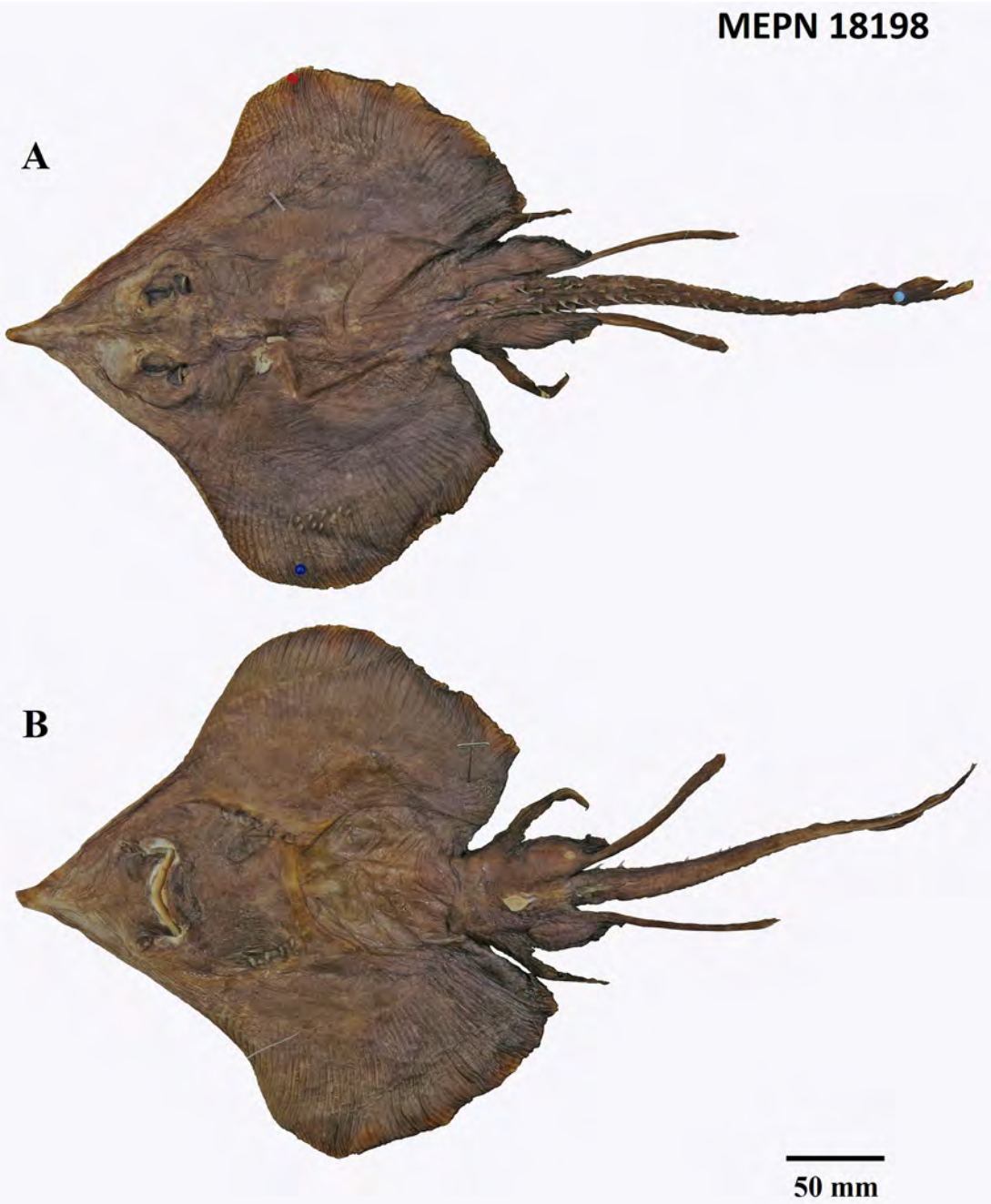

FIGURE 2. *Notoraja martinezi* **sp. nov.**, male holotype (MEPN 18198) photographed after specimen preservation: A. dorsal surface; B. ventral surface.

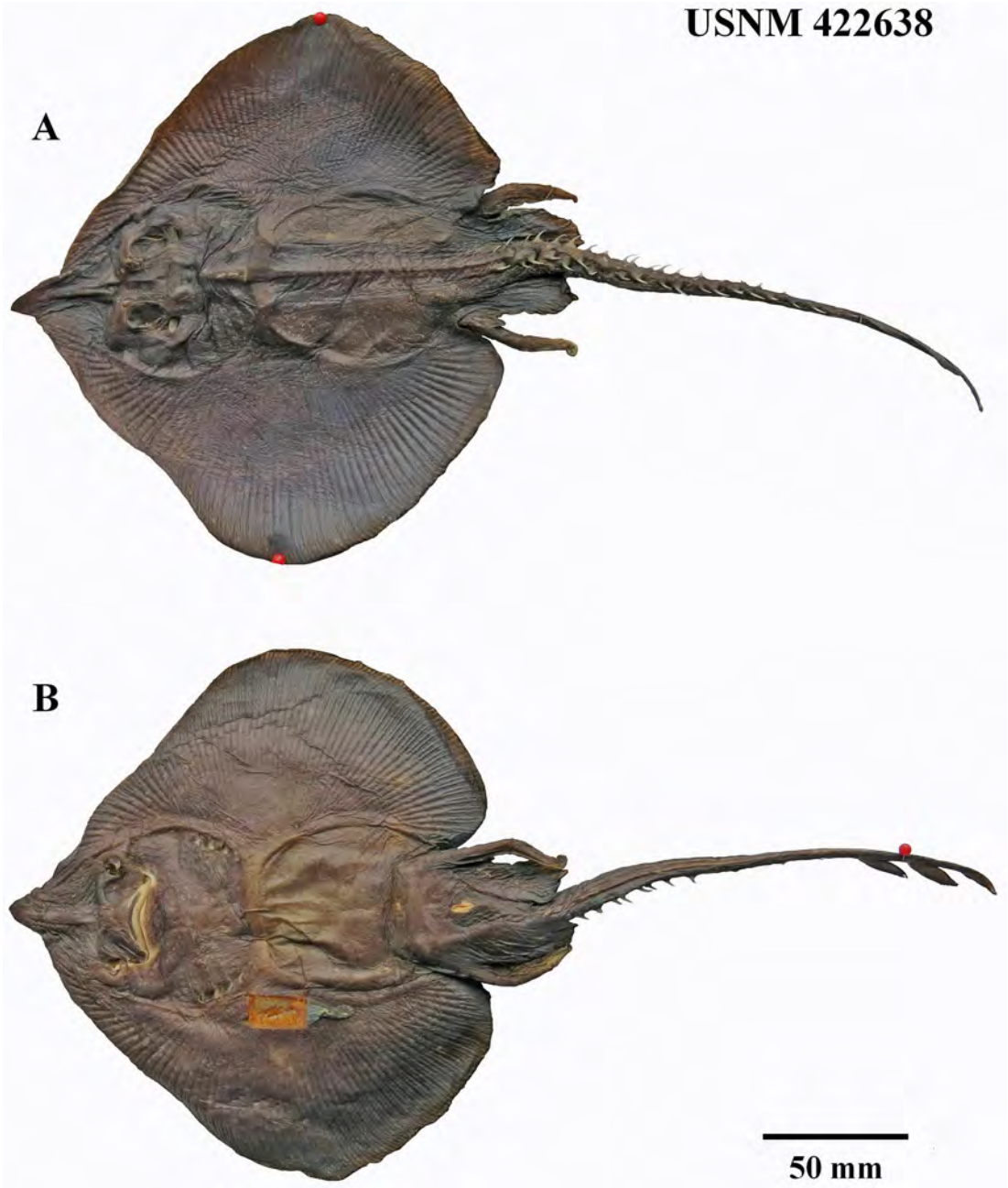

FIGURE 3. *Notoraja martinezi* **sp. nov.**, juvenile female paratype USNM 422638 preserved: A. dorsal surface; B. ventral surface.

Meristics. Tooth rows in upper jaw 42 (38–44); tooth series in upper jaw 5 (4–5); tooth rows in lower jaw 38 (36–42); tooth series in lower jaw 12 (5–7). Pectoral propterygial radials 25 (27–28); mesopterygial radials 21 (15–16); metapterygial radials 19 (20–23); total radials 65 (63–65); pelvic fin radials 10 (10–12). Monospondylous centra 25 (24–26); predorsal diplospondylous centra 58 (60–65); total predorsal centra 83 (85–91); total diplospondylous centra 93 (98–102); caudal centra 20 (22–25); total centra 118 (123–128).

Coloration. When fresh, dorsal surface of disc uniformly dark. Purplish-brown in male holotype, outer margins of disc narrowly bluish edged in females; tail, dorsal fins and tail folds dark brown dorsally. Ventral surface of disc, pelvic fins, and tail are dark brown or brownish black when preserved. Mouth edges white.

Etymology. The new species is named in recognition of Jimmy Martínez, an Ecuadorian Biologist, who collected and kindly provided the holotype of the new species. The proposed common name is barbedwire-tailed skate in allusion to the enlarged, randomly patterned tail thorns giving it a barbedwire-like appearance.

TABLE 1. Morphometrics of the holotype (*) and paratypes of *Notoraja martinezi*, **sp. nov.**, expressed as % of total length.

	MEPN 18198* Mature male		USNM 421575 Immature female		USNM 421352 Immature female		USNM 422638 Immature female	
	mm	% TL	mm	% TL	mm	% TL	mm	% TL
Total length	475		328		243		346	
Disc width		54.7		55.2		53.1		51.7
Disc length		51.6		54.3		49.0		50.0
Snout to maximum disc width		30.5		29.3		26.3		28.3
Snout length (preorbital)		14.9		14.9		13.2		13.0
Snout to spiracle (direct)		18.5		19.5		16.9		18.5
Snout to spiracle (straight)		34.2		33.1		30.2		33.0
Snout base width at spiracles		24.4		29.9		27.2		30.1
Head length (dorsal)		21.3		20.4		18.9		19.4
Orbit diameter		3.4		3.0		3.3		3.5
Orbit and spiracle length		0.4		0.6		0.4		0.6
Spiracle length		2.3		1.8		2.1		1.7
Distance between orbits		5.1		4.6		4.5		4.3
Distance between spiracles		6.3		7.6		6.6		7.5
Distance snout to cloaca		47.6		47.3		44.4		47.1
Cloaca to first dorsal fin		37.3		39.0		40.3		38.2
Cloaca to second dorsal fin		42.1		42.1		46.1		43.4
Cloaca to caudal-fin origin		46.5		46.6		51.0		48.0
Cloaca to tail tip		50.1		53.4		56.0		52.6
Snout length (pre upper jaw)		15.2		14.3		12.8		13.0
Prenasal length		13.7		11.0		14.0		12.4
Mouth width		8.6		7.3		7.0		8.4
Distance between nostrils		8.4		7.9		6.6		7.8
Nasal curtain length		5.9		4.0		2.5		4.0
Nasal curtain total width		8.4		8.8		7.8		9.5
Nasal curtain (minimum width)		7.6		7.3		6.6		8.7
Nasal curtain (lobe width)		1.3		1.5		1.6		1.7
Width of first gill opening		1.5		1.8		1.2		1.2
Width of third gill opening		1.5		1.8		1.2		0.9
Width of fifth gill opening		1.1		1.5		1.2		0.9
Distance between first gill openings		12.8		14.6		12.8		14.7
Distance between fifth gill openings		8.8		10.1		8.6		8.7
Clasper (post cloacal length)		20.8						
Clasper (inner length)		23.8						
Length of anterior pelvic-fin lobe		13.1		16.8		16.5		16.2
Width of anterior pelvic-fin lobe		2.7		2.4		2.1		1.7
Length of posterior pelvic-fin lobe		10.1		9.8		7.8		9.2

.....*continued on the next page*

TABLE 1. (Continued)

	MEPN 18198* Mature male		USNM 421575 Immature female		USNM 421352 Immature female		USNM 422638 Immature female	
	mm	% TL	mm	% TL	mm	% TL	mm	% TL
Pelvic fin base width		9.3		8.8		9.1		10.1
Tail at axil pelvic fins (width)		3.2		3.7		2.9		2.9
Tail at axil pelvic fins (height)		2.1		2.7		2.1		2.0
Tail at midlength (width)		1.9		2.1		1.6		1.4
Tail at midlength (height)		1.1		1.2		1.2		1.2
Tail at first dorsal-fin origin (width)		1.3		0.9		0.8		0.9
Tail at first dorsal-fin origin (height)		0.8		0.9		0.4		0.6
First dorsal-fin base (lenght)		3.8		2.7		2.9		2.6
First dorsal-fin (height)		1.7		1.2		1.2		1.2
Second dorsal-fin base (lenght)		1.9		1.8		0.4		1.7
Second dorsal-fin (height)		3.4		2.7		2.5		2.6
Interdorsal fin space		3.2		1.2		4.5		2.3
Caudal fin length		3.6		4.9		4.9		4.0

Distribution. The new species at present is the only known representative of the genus *Notoraja* from the eastern Pacific, occurring between Costa Rica and Ecuador (Fig. 8). This is the only known representative of the genus *Notoraja* found to occur outside the western Indo-Pacific. The depth range of 1256–1472 m makes it the deepest occurring species in the genus. Other *Notoraja* species occurring to similar depths include *N. azurea* and *N. sapphira* at 1440 and 1313 m deep, respectively (McEachran & Last, 2008; Séret & Last, 2009).

Size. *Notoraja martinezi* reaches a maximum length of at least 475 mm TL for an adult male, while the largest female is 346 mm TL; female maturity was not determined. The size at birth is not known, but the smallest paratype is 243 mm TL.

Comparisons. Members of the genus *Notoraja* can be distinguished from similar skates in other genera of Arhynchobatidae by its long tail, which is more than 50% of TL (Ebert, 2014). *Notoraja martinezi* differs in external morphology from its congeners by the presence of strong and enlarged caudal thorns in adults and juveniles of both sexes. Additionally, the lateral margins of the rostrum of *N. martinezi* are less convex than in the other members of this genus and anterior lobes of pelvic fins are longer.

Coloration of described species of *Notoraja* can vary from dark bluish in *N. azurea* and *N. saphira*, to light brown in *N. ochroderma*, *N. hirticauda*, *N. alisae*, *N. inustata* and *N. fijiensis*, and a pale grayish freckled disc in *N. sticta*. Thus, in terms of shape and color, the species that are more similar to *N. martinezi* are *N. azurea* and *N. saphira*, which also become dark brownish after fixation. The type specimens of *N. martinezi* are largely free of dermal denticles along the disc, with some randomly scattered small, fine dermal denticles restricted to the anterior margins up to the level of the pectoral girdle, anteriorly located with respect to the alar thorns in the male. A single preorbital thorn in front of each orbit is present in *N. martinezi* specimens of both sexes. In contrast, adults of *N. azurea* have few dermal denticles along the margin of the disc at the level of orbits and spiracles, and along the midline of the disc. In addition, juvenile specimens of the latter also have dermal denticles along anterior margin of disc, cranium, and along disc midline. The holotype of this species exhibits a single preorbital and a postorbital thorn, which is also a useful trait to differentiate *N. azurea* from *N. martinezi*. *Notoraja saphira* also shows a single preorbital thorn, but is much smaller than those of *N. martinezi*. Moreover, the rostrum of *N. sapphira* is shorter and more convex than the rostrum of *N. martinezi*. The anterior lobes of pelvic fins of both *N. azurea* and *N. saphira* are broader and shorter than those of *N. martinezi*.

Internally, the vertebral counts can also be used as a taxonomic character in this genus. Predorsal caudal vertebral count in this study was lower than in other congeners, ranging from 58–65 in *N. martinezi*, versus 70–89 in the others. The only similar counts have been reported for the type species, *N. tobitukai*, which has 63–70. Total predorsal vertebrate counts ranged from 83–91, which is lower than what was observed in other species of the genus, ranging from 95–119. Similarly to the other vertebrae counts, the total diplospondylous vertebral counts in

N. martinezi were also lower than they were for all other species, with 93–102 and 101–127, respectively. Total vertebral counts were in a lower range when compared to other congeners, being between 118–128 for *N. martinezi* and 126–152 for all other species of *Notoraja*.

Molecular evidence supports the placement of this new species in the genus *Notoraja* and further confirms its separation from *N. azurea* and *N. lira* (G. Naylor, College of Charleston, pers. comm.).

FIGURE 4. *Notoraja martinezi* **sp. nov.**, male holotype (MEPN 18198) preserved: Ventral view of head of *Notoraja martinezi* **sp. nov.**, showing rostrum, oronasal region and tooth band.

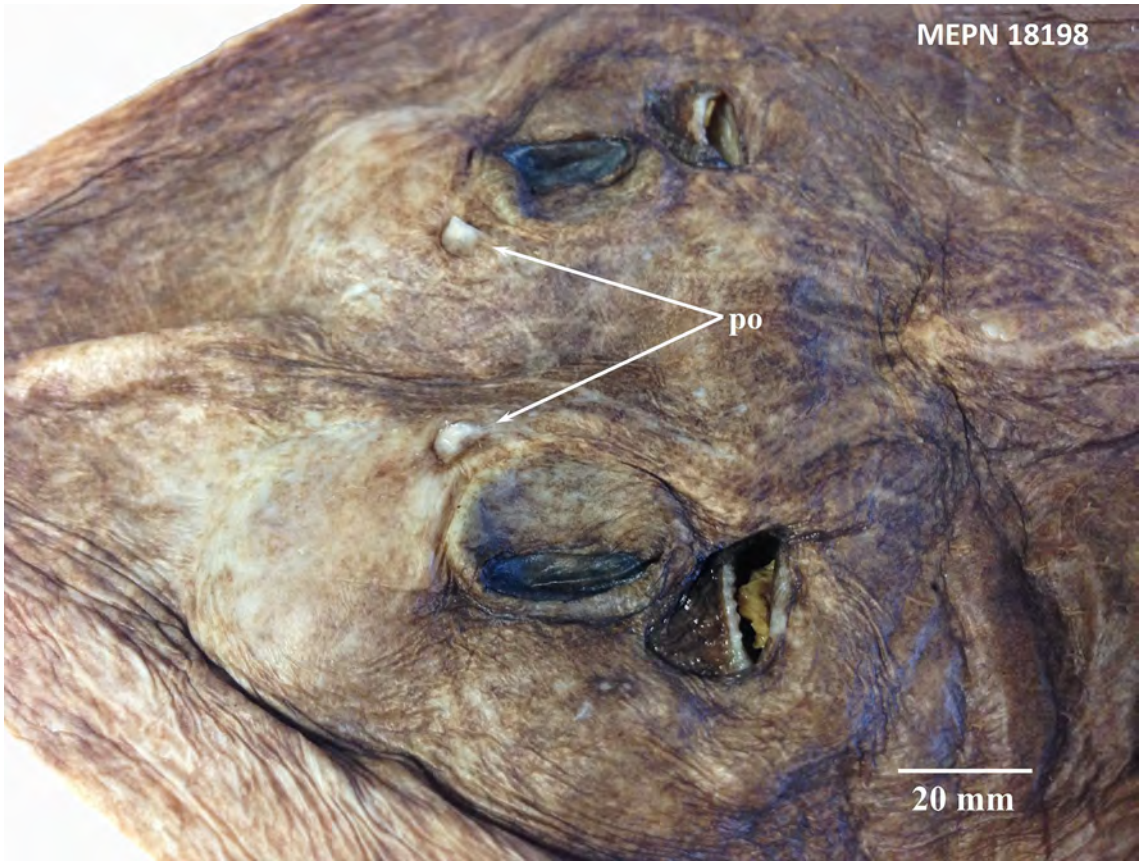

FIGURE 5. *Notoraja martinezi* **sp. nov.**, male holotype (MEPN 18198) preserved: Dorsal view of head, preorbital thorns (po), orbito-spiraclar and nuchal regions

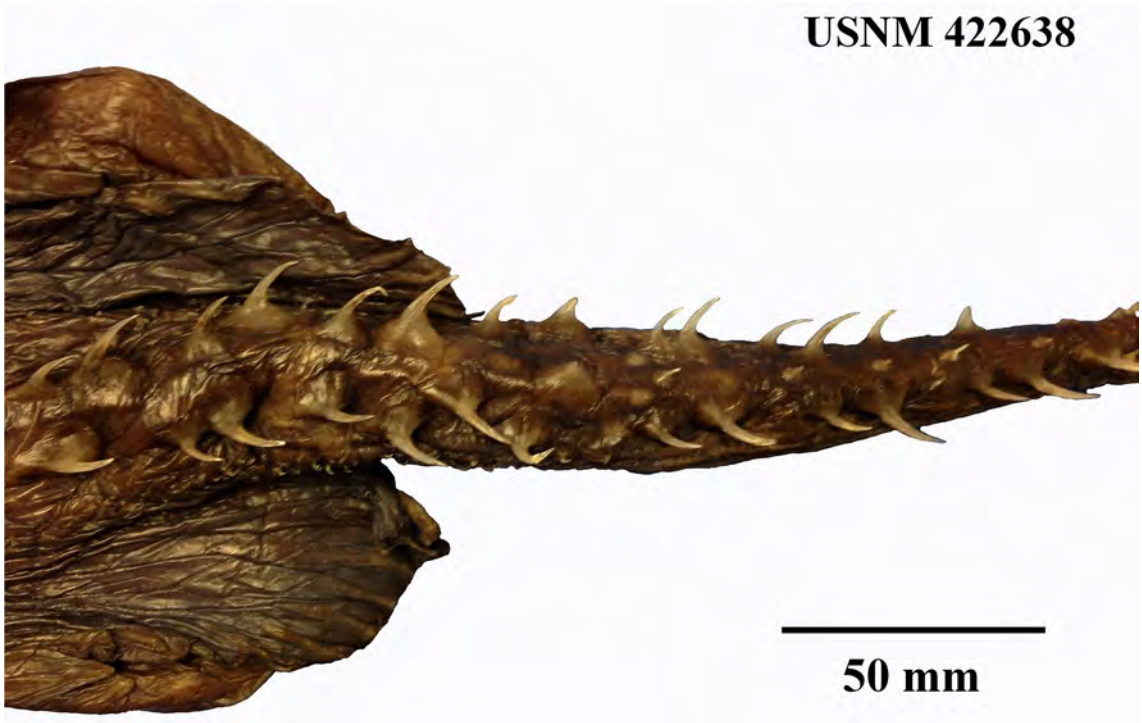

FIGURE 6. Dorsal view of tail thorns of *Notoraja martinezi* **sp. nov.**, female paratype (USNM 422638).

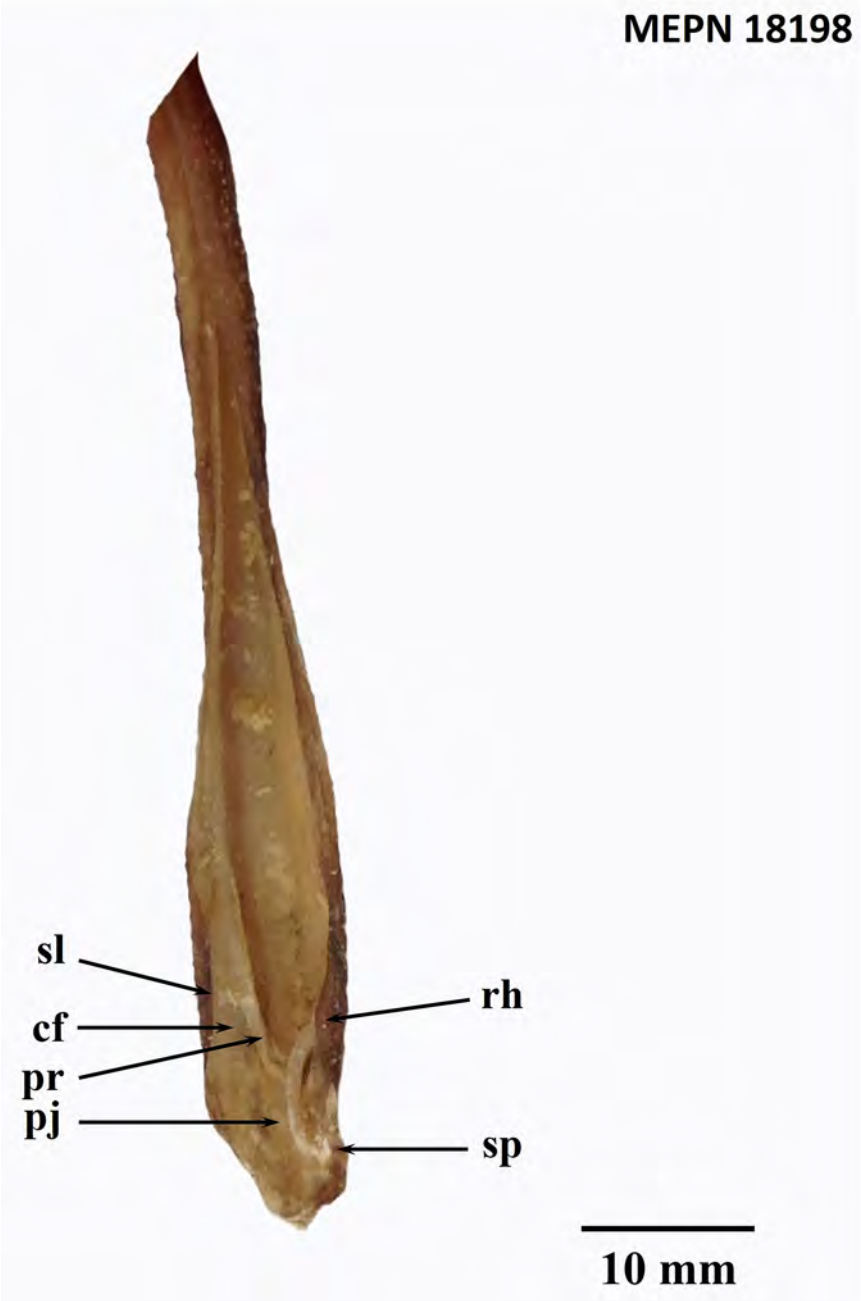

FIGURE 7. Right clasper of *Notoraja martinezi* **sp. nov.**, adult male holotype (MEPN 18198). Clef (cf), projection (pj), pseudorhipidion (pr), rhipidion (rh), slit (sl), spike (sp).

Finally, all other known species of the genus *Notoraja* until now have been reported from the western Pacific and eastern Indian oceans (Hiyama 1940, McEachran & Last 1994, 2008, Last & McEachran 2006, Séret & Last 2009, 2012). *Notoraja martinezi* is the first, and presently only known species of this genus that has been described from the Eastern Pacific Ocean.

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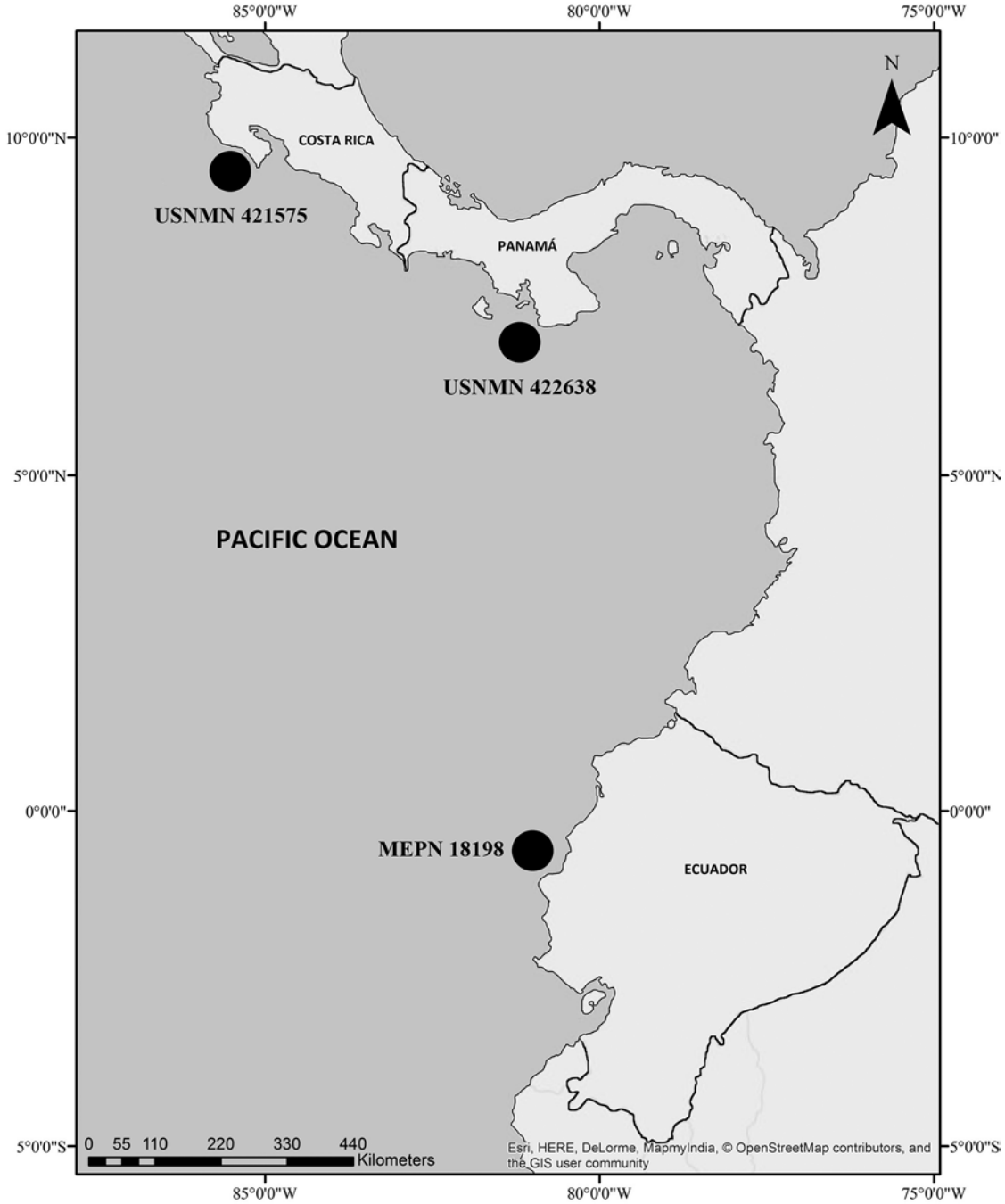

FIGURE 8. Distribution map of *Notoraja martinezi* **sp. nov.** ArcGIS v10.3, Environmental Systems Research Institute.

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