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A new guitarfish from the Gulf of California (Batoidea: Rhinobatidae)

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by

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ABSTRACT OF THE THESIS

A new guitarfish from the Gulf of California (Batoidea: Rhinobatidae)

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Professor Donald G Buth, Chair

A new guitarfish is described based on 75 specimens obtained from the Gulf of California. Sixty-three morphometric measurements were taken on all specimens. Measurements were also taken on four congeners in replicates of 10 individuals. A principal component analysis and linear discriminant analysis were performed on these morphometric data for discrimination and classification. This new species is most similar to *Pseudobatos productus* but differs in having a narrower disc width (30-35% vs. 36-38% TL), shorter distance from nostril to disc margin (2.8%-4.0% vs. 4.2-5.2% TL), narrower disc width at anterior orbit (12-19% vs. 20-22% TL) and a narrower tip of nose width (3% vs. 4-6% TL). This species is also less densely scaled between the orbits and has less pronounced rostral thorns when compared to *Pseudobatos productus*. A key to the guitarfishes of the Gulf of California is provided.

The thesis of Kelsi Marie Rutledge is approved.

Malcolm S Gordon

Noa Pinter-Wollman

Donald G Buth, Committee Chair

University of California, Los Angeles

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I dedicate this thesis to Derek Kirkbride.

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Introduction

The genus *Pseudobatos* was recently recognized in the redefinition of the family-level classification of Rhinopristiformes (Last et al., 2016a). This genus was found to be highly divergent from the rest of its family based on mitochondrial sequence data (Last et al., 2016a, Last et al., 2016b). This genus contains seven species, five of which are found in the Northeastern Pacific: *Pseudobatos productus* (Ayres 1854), *Pseudobatos glaucostigmus* (Jordan and Gilbert, 1883), *Pseudobatos leucorhynchus* (Gunther 1867), *Pseudobatos planiceps* (Garman 1880) and *Pseudobatos prahli* (Acero and Franke 1995). Of these five, three are found in the Gulf of California: *P. productus, P. glaucostigmus* and *P. leucorhynchus*.

In the late 1940s and 1950s, UCLA ichthyologist Boyd Walker, and colleagues caught 75 specimens of *Pseudobatos* in the Gulf of California (San Felipe to Guaymas) that he recognized as undescribed. No tissue samples were taken at the time of collection and genetic analysis could not be performed. These specimens are formally described here and distinguished by multiple morphological differences. This new species differs from its congeners in having a narrower disc width, shorter distance from nostril to disc margin, narrower disc width at anterior orbit, narrower tip of nose width, a light brown snout free of spots, very small or absent thorns around orbits and snout and fewer scales between the orbits.

Materials and methods

Morphometric measures follow those developed at a workshop on morphometric techniques developed for the family Rhinobatidae (Last et al., 2004; Last et al., 2014; Last et al., 2016a). Refinements were made to the existing convention, which include: snout length, spiracle length, preoral length, mouth width, and pelvic fin insertion to dorsal fin origin. These changes are defined as: snout length, “direct length from the snout tip to the posterior cartilaginous edge

of the sharply defined nasal capsule adjacent the orbit (forward margin of eye socket)"; spiracle length, "greatest length of the main cavity"; preoral length, "direct length from the snout to the posterior edge of upper jaw at its symphysis"; mouth width, "taken across the exposed width"; pelvic-fin insertion to dorsal-fin origin, "horizontal distance from the pelvic insertion to the origin of the first dorsal fin" (Last et al., 2004). New measurements of the nasal region were added to define the three main nasal lobes as described in Last (2004). These include: an anterior nasal flap (nasal valve of Norman, 1926) "ordering the inner margin of the nostril"; a posterolateral nasal flap "originating along the lateral margin of the anterior (incurrent) aperture and extending variably along the lateral margin of the nostril"; and posterior nasal flap "mainly bordering the posterior (excurrent) nasal aperture" (Last, 2004). Dorsal fin measurements parallel the requiem shark drawn in Compagno (1984) and did not require any refinements. "Tip of nose width" was also created to distinguish nose shape between the new species and *P. productus*, it is defined as: "horizontal distance across tip of nose measured directly behind nasal tassel." If nasal tassel was absent, distance was measured as the "narrowest region of snout."

Sixty-three morphometric characters were measured on each of the specimens using electronic calipers (Table 1). Measurements were also taken on ten replicates of *P. productus*, *P. glaucostigmus* and *P. leucorhynchus. Pseudobatos prahli* and *P. planiceps,* found in South and Central America, were not able to be obtained due to their rarity in museum collections. In the case of a range extension, pictures of *P. prahli* and *P. planiceps* were examined.

In order to reduce measurement error and enhance precision, measurements were all taken with the same calipers by the same person. To improve accuracy, the first five undescribed specimens were measured in their entirety twice, with any discrepancies between the first and

second measurement leading to a third and final measurement. The third measurement that agreed with one of the first two was the measurement that was recorded.

To determine whether there were distinct morphological differences between the 75 undescribed species and the other three species occurring in the Gulf of California, a principal component analysis (PCA) and a linear discriminant analysis (LDA) were performed. The PCA was performed on the 63 morphometric characters used to distinguish guitarfishes (Last et al., 2004). Additionally, a LDA was performed on the 63 morphometric characters to determine which measurements are most informative in distinguishing species. All analyses were performed using packages factoextra (Kassambara and Mundt, 2017), MASS (Venables et al., 2002), devtools (Wickham et al., 2018) and flipMultivariates in R v. 3.3.3 (R Core Team 2017). Plots were created using the R function, ggplot2 and ggbiplot (Wickham, 2009).

Examined material of *Pseudobatos* is deposited in the following institutions (abbreviations follow Sabaj Pérez, 2016): University of California Los Angeles Ichthyology Collection, Los Angeles (UCLA); Natural History Museuum of Los Angeles County (LACM); Scripps Research Institution of Oceanography, San Diego (SIO).

Results

Pseudobatos buthi n. sp. (Fig.1)

Type material.

Holotype— UCLA W50-189, adult male, 471.1 mm TL, Gulf of California, San Felipe 31.0251° N, 114.8408° W, 2 m deep, very fine, dark sand. Clear salt water, low incoming tide. 45-135 m offshore. Temp. 19-20° C. 30 m beach seine. 24 November, 1950.

Allotype— UCLA W49-122, adult female, 383.6 mm TL, Gulf of California, San Felipe, 1.1 m deep, muddy sand. Turbid salt water. 76 m offshore. Temp 24° C. 30 m beach seine. 25th March, 1949.

Paratypes— (73 specimens) UCLA W52-45, 4 females, 288.6-358.8 mm TL, 6 males, 275.2-324.7 mm TL, Gulf of California Punta San Fermin; UCLA W57-155, female, 376.4 mm TL, Gulf of California San Felipe; UCLA W55-200, female, 362.8 mm TL, Gulf of California San Felipe; UCLA W55-2, female, 358.7 mm TL, Gulf of California Punta Diggs; UCLA W49-126, male, 342.0 mm TL, Gulf of California San Felipe; UCLA W55-1, female, 356.5 mm TL, Gulf of California San Felipe; UCLA W49-55, male, 320.9 mm TL, female, 277.3 mm TL, Gulf of California Sonora; UCLA W56-28, male, 306.9 mm TL, female, 304.8 mm TL, Gulf of California Sonora Punta Lobos; UCLA W54-366, female, 278.2 mm TL, male, 252.8 mm TL, Gulf of California Punta Diggs; UCLA W54-367, male, 264.3 mm TL, Gulf of California Playas Almejas; UCLA W50-189, 2 males, 490.6-501.9 mm TL, Gulf of California San Felipe; UCLA W49-423, 2 females, 389.6-392.6 mm TL, male, 379.9 mm TL, Gulf of California San Felipe; UCLA W50-190, female, 386.2 mm TL, male, 388.3 mm TL, Gulf of California San Felipe; UCLA W49-91, female, 293.3, male, 295.9, Gulf of California San Felipe; UCLA W54-365, 5 males, 215.9-333.1 mm TL, female, 269.2 mm TL, Gulf of California Punta Majora and Punta Eusenada Blanca; UCLA W49-122, 6 females, 251.6-402.1 mm TL, 7 males, 337.1-414.7, Gulf of California San Felipe; UCLA W56-73, 3 females, 535.7-599.6 mm TL, 2 males, 412.3-599.4 mm TL, Gulf of California Sonora Bocochibampo; UCLA W50-61, 3 females, 244.4-315.9 mm TL, male, 286.5 mm TL, Gulf of California Sonora Puerto Libertad; UCLA W50-57, 3 females, 326.8-585.3, 8 males, 297.4-516.3, Gulf of California Sonora Bahia Kino; UCLA W49-119, male, 382.7 mm TL, Gulf of California San Felipe; UCLA W50-67, male, 543.1 mm TL, Gulf of

California Sonora Puerto Libertad; UCLA W52-16, female, 417.4 mm TL, Gulf of California Sonora Estero Soblado. SIO 61-82, female, 400 mm TL, Mexico Gulf of California San Felipe. SIO 61-183, male, 460.2 mm TL, Mexico Gulf of California San Felipe.

Diagnosis

Pseudobatos buthi n. sp. is distinguished from *P. glaucostigmus* (Fig. 2a) in having a nasal tassel, uniform coloration, a slightly narrower maximum disc width and disc width anterior orbit, a larger head length, longer snout length, shorter anterior nasal flap length, smaller nostril length and a smaller body width at first dorsal origin.

Pseudobatos buthi n. sp. is distinguished from *P. leucorhynchus* (Fig. 2b) in having a nasal tassel, brown rostrum, smaller snout to first dorsal origin, shorter snout to lower caudal origin, a slightly narrower disc width anterior orbit, a thinner body at first dorsal origin, shorter anterior nasal flap base length and a shorter nostril length.

Pseudobatos buthi n. sp. is most similar to *P. productus* (Fig. 2) but differs in having a narrower disc width (30-35% vs. 36-38% TL), shorter distance from nostril to disc margin (2.8%-4.0% vs. 4.2-5.2% TL), narrower disc width at anterior orbit (12-19% vs. 20-22% TL) and a narrower tip of nose width (3% vs. 4-6% TL). There is some overlap in additional traits but *P. buthi* n. sp. generally has a slightly longer snout length (19% vs. 17% TL), larger interorbital width (4.1-6.2% vs. 3.4-5.6% TL), larger posterior nasal flap width (1.3% vs. 2.3% TL), smaller nostril length (4.0% vs. 4.5% TL), slightly shorter anterior nasal flap base length (1.8% vs. 2.1% TL), slightly smaller posterior nasal flap width (0.9% vs. 1.1% TL), slightly shorter distance between anterior nasal flaps (4.7% vs. 5.4% TL), shorter distance between first gill openings (11.6% vs. 14.1% TL), shorter distance between fifth gill openings (8.8% vs. 10.0% TL), shorter snout to first dorsal origin (53% vs. 57% TL), shorter snout to pelvic fin origin (33.0% vs. 37.7%

TL), smaller snout to anterior vent length (38% vs. 41% TL), thinner tail (5.2% vs. 8.3% TL), smaller body width at first dorsal (4.6% vs. 6.4% TL), smaller maximum body depth (7.5% vs. 8.7% TL), and a thinner body depth at pelvic fin insertion (4-7% vs. 5-8% TL). *P. buthi* n. sp also has a less prominent scale patch between orbits and a less thorny rostrum, with very small or absent thorns running down the snout and between orbits.

Statistical Analysis

A scree plot of the PC variance found that the first PC described the majority of the variance (~97%), which mainly loaded with body size. The PCA resulted in some overlap between all three species of guitarfishes (Fig. 3). *P. leucorhynchus* overlapped heavily with *P. glaucostigmus*. *P. productus* overlapped heavily with *P. buthi* n. sp. Other non-continuous variables such as snout color and spots may be better characters to distinguish these species. While Last's (2004) 63 characters may be useful in distinguishing genera, the results of this PCA suggest they may not be as informative within this genus. Only 3% of the variance between these species was described by characters other than body size. PC2 and PC3 primarily loaded with interspiracular width, spiracle length and nostril length (Table 2). *P. buthi* n. sp. has the smallest average nostril length and a larger spiracle length than *P. glaucostigmus* and *P. leucorhynchus*. *Pseudobatos productus* has the largest average interspiracular width. Gender was also compared to determine if grouping was influenced by dimorphism. Gender did not appear to have a clear intraspecific grouping pattern.

The LDA performed on all 63 measurements found that the characters describing nasal structure best distinguish these species (Fig. 4). LD1 was primarily loaded with body size. LD2 primarily loaded with nostril length and anterior aperture width loading negatively and anterior nasal flap base length and posterolateral nasal flap width loading positively. *P. glaucostigmus*

loads negatively on LD2 with a larger nostril length and smaller anterior aperture width. LD3 primarily loaded with snout length, anterior aperture width and distance across anterior nasal aperture loading negatively and nostril length and distance from nostril to disc margin loading positively (Table 3). *Pseudobatos buthi* n. sp. loaded negatively with a longer snout length a shorter distance across anterior nasal apertures. *P. productus* loaded positively on LD3 with a larger nostril length and larger distance from nostril to disc margin.

Description

Disc wedge shaped, anterior margin straight, angle anterior to eyes about 60°; outer corner of pectoral fins mostly rounded, length 1.28 times width in the large male holotype; smaller immature paratypes length 1.17 times width (Table 1). Pelvic fins relatively short, base length about .93 of inner margin; total length 1.95 times their base length, 1.43 times width; anterior margin weakly weakly convex, apex broadly rounded, posterior margin almost straight. Tail slender; in cross-section nearly flat ventrally, rounded dorsally; tail length from anterior cloaca 1.41 times precloacal length, 1.42 times disc length, 5.57 times body width at pelvic-fin insertions; tail width 2.02 times depth at pelvic-fin insertions, 2.37 at first dorsal-fin origin, 3.77 at second dorsal-fin origin. Dermal fold lateral on tail, originating slightly anterior to free rear tip of pelvic fin, reaching just behind ventral caudal-fin origin; fold moderately narrow, maximum width in interdorsal space about 2.28 times width of posterior nasal flap. Head moderately to very long, ventral length 28.25% (26.2–33.5%) TL; snout moderately long and pointed; preoral snout length long (16.4-22%), 2.85 times mouth width in holotype but up to 3.5 times mouth width in paratypes, 7.09 (6.61–8.87) times internarial distance, 1.79 (1.66–2.23) times dorsal caudal-fin margin, 5.44 (5.07–6.81) times distance from nostril to margin of disc; presocket snout length 2.69 (2.49–3.35) times interspiracular width, 4.49 (4.16–5.52) times orbit diameter;

interorbital space almost flat, rather narrow; eyes moderately small, slightly elevated, orbit diameter 1.59 (1.51–1.87) times spiracle length, 1.21 (1.15–1.36) times interorbital width. Spiracle lunate, moderately large; two weakly compressed spiracular folds on posterior margin, innermost fold half or less length of outer fold; distance between bases of folds equal to length of inner fold. Nostril length relatively small (3.6-4.6), oblique, nasal flaps well developed; anterior aperture suboval, width well exceeding length; nostril length 3.69 times anterior aperture width, 2.19 times anterior nasal-flap base length, 1.23 times distance from nostril to disc margin, 1.61 times internarial width. Anterior nasal flap narrow with long, bluntly pointed process that curves posteriorly; flap base 1.29 times its width at process, 1.59 times anterior aperture width; inserted well into internarial space, not at nostril margin, distance between their insertions 4.37 in distance between lateral margins of anterior apertures, 2.5 in internarial width; process of flap almost as long as it is wide at its base, overlapping posterolateral nasal flap and determining hind margin of anterior aperture. Posterolateral nasal flap lobe-like, width uniform, length 3.88 times width; originating at lateral extremity of anterior nasal aperture, extending posteriorly as free fold (below anterior fold and above posterior fold along lateral margin of nostril) to about level of insertion of anterior nasal flap. Posterior nasal flap strongly lobelike, base length 2.05 times its width, not reaching end of nostril, inserted well forward of posterior tip; width smaller than anterior aperture width, 1.68 times posterolateral nasal-flap width. Nasal lamellae 43. Mouth width large, width 1.56 times nostril length, 6.73 (6.33–7.78) in precloacal length; positioned below hind margin of orbit. Upper jaw almost horizontal, upper lip slightly concave; lower lip pronounced, separated from oral groove by ridges of strongly corrugated skin; weak lateral grooves around corners of mouth. Teeth small, blunt, crowns rhomboidal with weak, pointed posterior cusps; teeth quincuncial; upper and lower jaw teeth similar in shape

and size; first upper tooth row 59. Gill openings weakly s-shaped; length of third gill slit 1.59, 9.11 in distance between fifth gill slits; distance between first gill slits 1.43 times distance between fifth gill slits; distance between fifth gill slits 3.67 times internarial distance, 1.46 times mouth width, 3.10 (2.87-3.67) times in ventral head length. Dorsal-fins short, relatively upright; apices acutely rounded rather than angular; anterior margins weakly convex; posterior margins almost straight to weakly concave; free rear tips forming right angle; first dorsal fin just barely taller than second, length of first 1.03 times its height, base length 2.05 times inner margin length; second dorsal-fin length 1.01 times its height, base length 2.50 times inner margin length. First dorsal-fin relatively close to pelvic-fin insertion, interspace 1.89 times interdorsal distance; interdorsal space relatively short, 1.79 times second dorsal-fin height, 2.60 times base of first dorsal-fin, 1.18 times interspace between second dorsal-fin insertion and upper origin of caudal fin (caudal peduncle length). Caudal fin small, dorsal caudal margin 1.26 times preventral margin length. Clasper slender, not fully calcified, relatively short, inner length of right clasper about 12% TL; tip acute. Dermal denticles minute, close-set, covering entire body; small or absent thornlets on rostral ridges, around orbits and spiracles, on each shoulder and in a median row on back between dorsal fins. Tip of nose with or without nasal tassel. Holotype without nasal tassel, however nasal tassel can be seen on allotype and other paratypes. Thorns and nasal tassel often absent or less pronounced on larger specimens. Ventral surface uniformly covered in minute denticles.

Preserved coloration Dorsal surface brownish gray, free of spots, nose lighter in coloration. Ventral surface evenly pale or with dark marking on snout tip.

Size To at least 599 mm TL.

Etymology Named in honor of my mentor, UCLA ichthyologist Donald Buth, who suggested this description and made available all type-series specimens in the UCLA Ichthyological Research Collection.

Distribution Shallow coastal regions of the Gulf of California to at least two meters depth (Fig. 5).

Remarks

Guitarfishes are difficult to distinguish within genera and traits are not often easily recognizable to the untrained eye. In an effort to aid in the identification process, a key to the guitarfishes of the Gulf of California was created. As described by Last et al. (2016a), members of the genus *Pseudobatos* are distinct from all other rhinobatids in their nasal morphology. This group is distinguished by having narrow, elongate posterior apertures, bilobed anterior nasal flaps, broad posterolateral nasal flaps and various other morphological differences. This new species, which is similar to *P. productus* in appearance and range, has a more narrow nose, less thorny, has a narrower disc width, shorter distance from nostril to disc margin and a narrower disc width anterior orbit. While there is some overlap in other morphometric characters, *P. buthi* n. sp. can also be distinguished by a smaller nostril length, shorter anterior nasal flap base length, smaller posterior and posterolateral nasal flap width and a shorter distance between anterior nasal flaps. Additionally, there appears to be wide variation in some of the traits of *P. buthi* n. sp (Table 1). For example, the snout length (14-19% TL) exhibited more size variation than *P. productus* (15-17% TL). Both *P. buthi* n. sp. and *P. productus* had large ranges in disc length, varying almost 10% (39-47% vs. 41-47% TL). This is likely due to the large range in specimen sizes (TL). While measurements were scaled as a percentage of TL, growth does not appear to be isometric, with tail length elongating as they grow. Juvenile specimens of *P. buthi* n. sp and *P.*

productus are easier to distinguish than adults, with pronounced differences in disc width, tip of nose width, denser scales between orbits and thorns along the rostrum (Fig. 6). Adult specimens of *P. productus* have less pronounced thorns and while disc width is still wider, it is more difficult to visually recognize. Additionally, disc length appears to be quite different in only juvenile specimens of *P. buthi* n. sp and *P. productus*, with *P. buthi* n. sp having a longer disc length than juvenile specimens of *P. productus* at the same total length (TL). This difference is not observed at larger sizes, suggesting these species may grow and develop differently; however, this would need to be explored further.

As previously mentioned, there is much taxonomic controversy within the family and the genus *Pseudobatos* is likely to change or be elevated with recent, unpublished nuclear DNA analysis (Peter Last, pers. comm.). While morphometric and statistical analyses highlight *P. buthi* n. sp. as distinct from its congeners, future genetic analysis would aid in determining the phylogenetic placement and characterization within this group. However, this would be contingent on further sampling to determine if *P. buthi* n. sp is still present in the Gulf of California. *Pseudobatos buthi* n. sp. was last caught in the Gulf of California in April 1962 (SIO 61-183).

Finally, there is more than just taxonomic research needed on this group. While the number of species descriptions of this group is continuing to increase, we lack a basic biological understanding of many of these species. The general biology and life history traits of 14 of the 31 species in the family Rhinobatidae are unknown, including comparative species from this description; *P. glaucostigmus*, *P. prahli* and *P. planiceps* from the Northeastern Pacific (Moore, 2017).

Comparative Material Examined

Pseudobatos productus: UCLA W76-2, 3 males, 276.4-408.4 mm TL, female 439.3 mm TL, California Los Angeles Co. Belmont Shore; UCLA W50-128, 2 females, 262.8-364.5 mm TL, 2 males, 298.5-346.1 mm TL, California Los Angeles Co. Long Beach; UCLA W49-375, 2 males, 229.7-379.6 mm TL, female, 242.7 mm TL, California Newport Bay; UCLA W50-128, 2 males, 251.2-279.8 mm TL, California Los Angeles Co. Long Beach; UCLA W52-248, 2 males, 239.0-250.3 mm TL, Mexico Gulf of California Bahia Santa Maria; UCLA W48-3, female, 216.9 mm TL, California San Pedro.

Pseudobatos glaucostigmus: UCLA W58-46, 2 females, 446.0-468.0 mm TL, 3 males, 443.3-459.0 mm TL, Mexico Gulf of California Sinaloa Bahia Topolobampo; UCLA W56-117, 2 females, 238.5-319.4 mm TL, male, 240.2, Mexico Gulf of California Sinaloa Bahia Topolobampo; UCLA W51-22, male, 334.7 mm TL, Mexico Gulf of California Sinaloa Camaron Beach; 6530-4 LACM, female, 325 mm TL, Mexico Gulf of California Sinaloa.
Pseudobatos leucorhynchus: UCLA W53-273, 3 males, 518.1-546.4 mm TL, female, 300.9 mm TL, Panama Panama Bay Rio Pacora; UCLA W53-317, female, 262.7, male, 206.6, Panama Golf of Panama Chimán; W58-278 LACM, 2 females, 353.2-442.0 mm TL, 2 males 386.2-515.2, Panama Panama Bay Vilzy.

Pseudobatos prahli and *Pseudobatos planiceps*: Images examined from FishBase and Last et al. (2016b).

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