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Redescription of *Aetobatus flagellum* (Bloch & Schneider, 1801), an endangered eagle ray (Myliobatoidea: Myliobatidae) from the Indo–West Pacific

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Abstract

The eagle ray *Aetobatus flagellum* (Bloch & Schneider, 1801) is redescribed based on new material from the Persian Gulf (Kuwait), Indonesia and Malaysia. A related but distinct species of *Aetobatus* from the western North Pacific, previously referred to as *A. flagellum*, is reported. *Aetobatus flagellum* is a medium-sized eagle ray which attains about 900 mm DW; males mature at approximately 500 mm DW. *Aetobatus flagellum* appears to be uncommon and restricted to estuary-influenced waters of the Indo–West Pacific. It is caught as gillnet bycatch where its habit of schooling, combined with probable small litter size, may make it particularly vulnerable to impacts from fisheries.

Key words: Myliobatidae, *Aetobatus flagellum,* batoid, Indo–West Pacific, *Aetobatus* sp., estuarine

Introduction

Eagle rays of the genus *Aetobatus* (Myliobatiformes: Myliobatidae) are benthopelagic and generally occur in shallow tropical and subtropical waters of the world. They differ from the other three genera of eagle rays, i.e. *Aetomylaeus*, *Myliobatis* and *Pteromylaeus*, in having a deeply notched nasal curtain, upper and lower teeth in a single row at all growth stages, and chevron-shaped teeth in the lower jaw (Capapé & Quignard, 1975; Compagno & Last, 1999). The most conspicuous members of this genus belong to the *Aetobatus narinari* complex, which until previously was considered to be monotypic with a circumtropical distribution. Recent morphological and molecular work has confirmed that it consists of at least two species, *Aetobatus narinari* (Euphrasen, 1790) in the Western Atlantic and *Aetobatus ocellatus* (Kuhl, 1823) in the Indo–West Pacific (Richards *et al*., 2009; Schluessel *et al*., 2010; White *et al*., 2010). White *et al.* (2010) also suggested that two other species, *Aetobatus laticeps* (Gill, 1865) in the Eastern Pacific and *A. latirostris* Duméril, 1861 from the Eastern Atlantic, are likely valid.
Other than the *A. narinari* species complex, the only remaining member of this genus currently recognised as valid is *Aetobatus flagellum* (Bloch & Schneider, 1801) from the Indo–West Pacific. This species was described as *Raja flagellum* by Bloch & Schneider (1801) based on two specimens (stuffed syntypes at the Museum für Naturkunde, Zoologisches Museum, ZMB, in Berlin) from the Coromandel Coast of southeastern India. In the original description, only a brief account was provided:

> *R. corpore duplo latiore quam longo, capite et pinnis pectoralibus acuminatis, pinna dorfali brevi, aculeo uno vel gemino, utrinque ferrato in bafi caudae flagelliformis, quadruplo longioris corpore.*

The only characters covered in this description are generic and not diagnostic, i.e. the wide disc (about double length), pointed head and ‘wings’ (pectoral fins), short dorsal fin, and a long whip-like tail about four times the length of the body. The description does include illustrations of the dorsal surface (in colour) and oronasal region of this species (Fig. 1). Blainville (1816) proposed *Aetobatus* as a subgenus of *Raia* for *Raja aquila* Linnaeus, 1758.

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Müller & Henle (1841) subsequently elevated *Aetobatus* to generic level, and designated *Raja flagellum* as *Aetobatus flagellum*. A point of interest here is that *Raja aquila* is now placed in the genus *Myliobatis*, and as a result, many subsequent authors consider *A. narinari* as the type species for the genus *Aetobatus*. More research into the type species designation of this genus is required. The deeply notched nasal curtain depicted in the oronasal illustration of Bloch & Schneider (1801) clearly shows this as a member of the genus *Aetobatus*. Fowler (1956) and Dor (1984) mistakenly considered *A. flagellum* to be a synonym of *A. narinari*.

There is little published information on the distribution and biology of *A. flagellum* in the Indo–West Pacific. Compagno & Last (1999) noted that the species was poorly-known, and noted its distribution as "Red Sea, India, Indonesia, and southern China; records from the eastern Atlantic and Hawaii require validation". Based on its apparent rarity, preference for coastal waters experiencing high and increasing levels of fishing effort, and inferred limiting life history characters, *A. flagellum* was assessed by the IUCN *Red List of Threatened Species* as 'Endangered' (White, 2006).

Aetobatus flagellum is considered to occur off Japan in the Northwest Pacific where in some locations it is particularly abundant and considered a pest of commercial shellfish beds and subject to predator control measures (Kawahara *et al*., 2004; Yamaguchi et al., 2005, Yamaguchi, 2007; Hagihara *et al*., 2008; Yagishita & Yamaguchi, 2009; A. Yamaguchi, pers. comm.). However, specimens recorded off Japan are very large in comparison to *A. flagellum* from elsewhere in its range where it is known to be a far smaller species than those in the *A. narinari* complex. It is likely that these are not conspecific taxa.

Surveys of fish landing sites by the authors and colleagues in the Persian Gulf, Indonesia and Malaysia (Borneo) over the last decade have resulted in the collection of fresh material of *A. flagellum*. In the present study, we provide a detailed redescription of *Aetobatus flagellum* (based on new material, from Kuwait in the Western Indian Ocean and Indonesia and Malaysia in the Western Central Pacific) and present information on its size, maturity and distribution to assist fisheries and conservation management in the future. The Northwest Pacific range of this species is discussed.

Methods

The syntypes were examined by P. Last (CSIRO) in November 2009 and photographs of these two stuffed specimens were examined by the authors; the syntypes were not measured as they were stuffed specimens. The size (disc width, DW), sex and, for males, maturity stage (based on level of clasper calcification) were recorded for individuals of *A. flagellum* observed during surveys of fish landing sites in Kuwait (in April 2008 and 2011) and Indonesia (2001–2011). Details on these respective fish landing sites surveys can be found in Moore *et al*. (2012) and White & Dharmadi (2007). Where possible, specimens of *A. flagellum* were retained as voucher specimens to enable comparison with other specimens in museum collections. Muscle tissue samples were taken from specimens collected in the field and stored in either 95% alcohol or DMSO until processed in the laboratory. Whole retained specimens were injected with 100% formalin (into gut cavity) and then fixed in a 10% formalin solution in the field. These specimens were subsequently stepped-up into 70% ethanol for long-term preservation. Specimens of *A. flagellum* in museum collections from India were examined by the first author (BMNH, MNHN) and images of specimens deposited at the USNM fish collection were also viewed and verified.

A total of 65 measurements were taken from all 20 retained specimens of *Aetobatus flagellum* by the senior author, following the methodology proposed by White *et al.* (2010). Since the syntypes are dried specimens, they were not measured for the purpose of this redescription. Meristics were obtained from 8 of these specimens (CSIRO H 4426–14, CSIRO H 6134–01, CSIRO H 6662–03 to –06, CSIRO H 7252–01, CSIRO H 7253–01). Meristic methodology generally follow Last & White (2008) for dasyatids, with some minor modifications: the first enlarged anterior element of the pelvic fin (with at least 4 and up to 6 distal segments fused at their bases) is counted as one; first synarcual centra are included in vertebral counts as there are no denticles to obscure centra (counts also provided without synarcual centra); pre-dorsal diplospondylous counts are used rather than pre-sting counts; intermediate pectoral-fin radial elements were assigned to a pterygial unit based on the relative level of overlap with each of the adjacent units; and distal propterygial and metapterygial elements were considered to form part of the main skeleton and were not incorporated into counts; the notochord of the tail was excluded from counts.

Specimens are referred to by the following prefixes for their registration numbers: BMNH, British Museum of Natural History, London; CSIRO, Australian National Fish Collection, Hobart; IPMB, Universiti Malaysia Sabah, Kota Kinabalu, Malaysia; IPPS, Institut Penyelidikan Perikanan Sarawak, Kuching, Sarawak; MNHN, Muséum national d'Histoire naturelle, Paris; MZB, Museum Zoologicum Bogoriense, Jakarta; RMNH, Rikjsmuseum van Natuurlkjke Histoire, Leiden; SMEC, Zoology Department of the Sabah State Museum, Kota Kinabalu, Malaysia; USNM, National Museum of Natural History, Smithsonian, Washington DC.

Aetobatus flagellum **(Bloch & Schneider, 1801)**
(Figures 1–6, Table 1)

Raja flagellum Bloch & Schneider, 1801: 361, pl. 73 (Coromandel Coast, India).
Aetobatis narinari—Day, 1878 (in part): 743, pl. 194, fig. 4 (misidentification, India).
Aëtobatis narinari—Day, 1889: 59–60, fig. 24; Blegvad, 1944: 55–56, fig. 23 (brief description, illustration after Day, 1878) (misidentification, Persian Gulf).
Aëtobatis flagellum—Annandale, 1909: 54–58, fig. 10a, pl. (fig. 5) (off Orissa Coast and Chilka Lake)
Aetobatis flagellum—Fowler, 1930: 507 (Hawaii; Indian Ocean)
Aetobatus narinari (in part)—Fowler, 1941: 471; Misra, 1947: 40; Dor, 1984: 20.

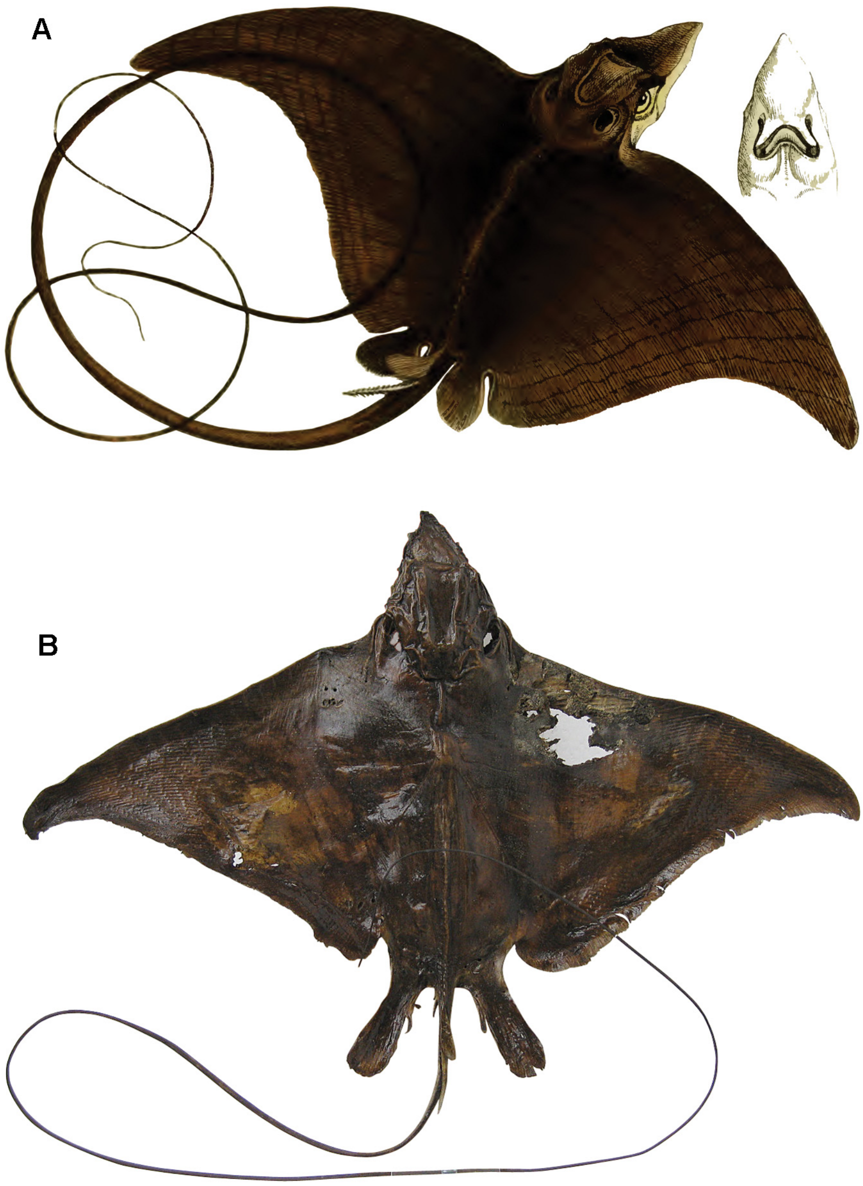

FIGURE 1. *Aetobatus flagellum*. A. original illustration from Bloch & Schneider (1801); B. dorsal view of stuffed syntype ZMB 31560.

Syntypes. ZMB 7845, male, coast of Coramandel, India, collected by M.E. Bloch; ZMB 31560, male, Tharangambadi (formerly Tranquebar), coast of Coramandel, India, collected by M.E. Bloch.

Other material examined. (20 specimens): BMNH 89.2.1.4205-8, 5 specimens (female 243 mm DW [653 mm TL], immature male 233 mm DW [548 mm TL], female 369 mm DW [1082 mm TL], female 289 mm DW [796 mm TL], female 290 mm DW), Madras (possibly), India; CSIRO H 4426–14, subadult male 446 mm DW, Muara Angke fish landing site, Jakarta, Indonesia, 17 Oct. 1995, collected by P. Last; CSIRO H 5485–02, immature male 350 mm DW (1017 mm TL), Kuching fish market, Sarawak, Malaysia, 02 May 1999, collected by P. Last & M. Manjaji; CSIRO H 6134–01, subadult male 431 mm DW (1260 mm TL), Muara Angke fish landing site, Jakarta, Indonesia, 20 May 2002, collected by W. White & Dharmadi; CSIRO H 6662–03, immature male 346 mm DW (1156 mm TL), CSIRO H 6662–04, immature male 306 mm DW (956 mm TL), CSIRO H 6662–05, female 326 mm DW, CSIRO H 6662–06, immature male 305 mm DW (1027 mm TL), Muara Baru fish landing site, Jakarta, Indonesia, 19 Apr. 2004, collected by W. White & Dharmadi; CSIRO H 7252–01, female 388 mm DW (1029 mm TL), Persian (Arabian) Gulf, Sharq fish market, Kuwait City, Kuwait, 29°23′ N, 47°58′ E, probably caught off Kuwait in <40 m, 01 Apr. 2011, collected by A. Moore; CSIRO H 7253–01, immature male 304 mm DW (853 mm TL), Persian (Arabian) Gulf, Sharq fish market, Kuwait City, Kuwait, 29°23′ N, 47°58′ E, probably caught off Kuwait in <40 m, 05 Apr. 2011, collected by A. Moore; MNHN 0000–2355 (largest of 2), immature male 322 mm DW (866 mm TL), Pondicherry, Coromandel Coast, India, 11°59' N, 79°50' E, collected by Boulenger; MNHN A-7949, adult male 543 mm DW, MNHN A-7957, female 578 mm DW (1392 mm TL), MNHN A-7958, 3 specimens (immature male 366 mm DW, female 301 mm DW [800 mm TL], immature male 329 mm DW [826 mm TL]), Malabar Coast, Northern Kerala, India, 11°00' N, 76°00' E, collected by Dussumier.

Specimens examined but not retained. female 746 mm DW, Persian (Arabian) Gulf, Sharq fish market, Kuwait City, Kuwait, 29°23′ N, 47°58′ E, probably caught off Kuwait in <40 m, 13 Apr. 2011, collected by A. Moore; male 570 mm DW (tissue accession GT2373, BW-A6099), Persian (Arabian) Gulf, Sharq fish market, Kuwait City, Kuwait, 2923′ N, 47°58′ E, probably caught off Kuwait in <40 m, 19 Apr. 2008, collected by A. Moore.

Specimens not examined but with images verified. USNM 206131, Caraioor fish market, near Jaffna Fort, Sri Lanka, 17 Mar. 1970; USNM 222684, fish market at Kalupittiya, Sri Lanka, 25 Jan. 1970, collected by C.C. Koenig; USNM 222690, St John's fish market, Colombo, Sri Lanka, 23 May 1970, collected by T. Iwamoto.

Diagnosis. A small *Aetobatus* (attaining about 900 mm DW) with the following combination of characters: dorsal surfaces uniformly brownish, without pale spots; tail very long (1.22–2.81 times DW); stinging spine(s) relatively long (6.2–16.2% DW); head long; rostral lobe long to very long (longest in adult males) with a narrowly pointed apex; teeth plates in a single row, those in lower jaw chevron-shaped; width of lower tooth plate about two thirds mouth width; pectoral-fin radials 89–96 (excluding propterygial radials anterior of eyes); total vertebral centra (including synarcual) 85–91; males mature by about 500 mm DW and females by about 746 mm DW.

TABLE 1. Ranges for the morphometric data for 20 specimens of *Aetobatus flagellum*. Measurements expressed as a percentage of disc width.

	n=20		
	Min.	Max.	Mean
Disc width (mm)	233	578	353.25
Total length	178.1	336.7	274.3
Pre-dorsal length	55.7	68.5	61.5
Disc, length	55.3	70.0	62.1
Snout to pectoral-fin insertion	49.4	63.0	54.9
Disc thickness	9.5	12.8	11.2
Snout to pectoral-fin origin	13.8	20.4	17.7
Posterior orbit to pectoral-fin insertion	39.5	45.8	42.2
Snout to maximum width (horiz.)	38.2	45.7	42.8
Pectoral-fin anterior margin	48.8	52.7	50.5
Pectoral-fin posterior margin	45.1	50.4	47.6
Pectoral-fin base length	38.2	43.8	40.7
Pectoral-fin inner margin	5.8	8.1	7.1

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

TABLE 1. (Continued)

	n=20		
	Min.	Max.	Mean
Head length (ventral)	26.0	33.5	29.9
Preorbital length	7.0	13.3	10.8
Preorbital length (horiz.)	4.1	10.4	8.0
Head width at pectoral-fin origins	14.8	17.8	16.5
Head height at pectoral-fin origins	9.0	10.5	9.7
Head width at mid-eye	12.5	15.9	14.1
Head height at mid-eye	7.5	10.1	8.7
Interorbital width	9.2	11.0	10.2
Interspiracular width	10.1	12.4	11.2
Spiracle length (longest)	4.8	6.8	5.6
Spiracle width (narrowest)	1.6	3.1	2.3
Orbit diameter	4.0	6.3	5.2
Eye diameter	1.9	3.0	2.2
Orbit and spiracle length	10.6	12.8	11.5
Preoral length	8.2	15.0	11.7
Prenasal length	7.3	11.6	9.1
Prenasal length (horiz.)	6.5	11.3	8.4
Rostral lobe width	8.3	12.8	9.9
Rostral lobe length	3.6	9.4	6.8
Mouth width	6.5	8.9	7.5
Internarial width (external)	4.1	5.6	5.0
Nasal curtain length	3.5	5.4	4.4
Nasal curtain width	6.1	7.9	7.2
Nostril length (internal)	2.4	4.2	3.3
Width of first gill slit	1.6	2.8	2.2
Width of third gill slit	1.8	2.6	2.1
Width of fifth gill slit	1.4	2.0	1.7
Distance between first gill slits	14.8	17.5	16.2
Distance between fifth gill slits	9.6	11.6	10.2
Tail at axil of pelvic fins (width)	2.9	3.9	3.4
Tail at axil of pelvic fins (height)	3.0	4.1	3.6
Tail at origin of stinging spine(s) (width)	1.3	2.7	2.0
Tail at origin of stinging spine(s) (height)	1.9	2.8	2.4
Pectoral-fin insertion to spine origin (horiz.)	10.4	14.8	12.5
Length of first stinging spine	6.2	16.2	10.3
Length of second stinging spine	12.0	13.5	13.0
Pectoral-fin insertion to dorsal-fin origin (horiz.)	5.7	10.1	7.4
Dorsal-fin length	4.7	7.8	6.3
Dorsal-fin anterior margin	5.6	7.9	6.8
Dorsal-fin height	2.6	4.5	3.3
Dorsal-fin posterior margin	1.8	3.5	2.7
Dorsal-fin inner margin	0.6	2.5	1.6
Snout to anterior cloaca	48.2	61.5	54.7
Cloaca anterior to tail tip	121.7	281.0	219.5
Cloaca anterior to stinging spine	11.5	16.1	13.1
Width across pelvic fin bases	9.7	12.8	11.5
Greatest span of pelvic fins	17.3	25.4	21.4
Pelvic-fin length	14.3	18.7	16.6
Pelvic-fin anterior margin	12.0	16.2	14.6
Pelvic-fin base	5.5	8.6	7.1
Pelvic-fin posterior margin	6.6	9.3	7.7
Pelvic-fin inner margin	9.0	13.3	11.1
Clasper outer length	6.4	6.4	6.4

Description. Disc diamond-shaped, broad but relatively short, width about 1.33–1.81 times disc length; anterior projection 3.15–4.22 in disc length; axis of greatest width of disc well posterior to scapular region, over abdominal cavity, its horizontal distance from snout tip 1.18–1.40 times in distance from tip of snout to pectoral-fin insertion; moderately deep, greatest thickness above scapular region and posterior head, thickness 7.83–10.57 in disc width; without denticles, or thorns; with a short, bony ridge on midline above scapular region. Pectoral fins very large, wing-like, narrowly triangular, weakly falcate; anterior margin concave basally, nearly straight for first two thirds, slightly to moderately convex distally; apex narrowly rounded to subangular, pectoral angle 54–61°; posterior margin moderately concave near apex, almost straight posteriorly; free rear tip broadly rounded; inner margin convex distally, becoming nearly straight basally; length of anterior margin 48.8–52.7% DW, 1.17–1.31 times its base length, inner margin 4.87–6.91 in its base; origin over anterior edge of spiracles; apex located just posteriorly to pectoral mid-base; insertion just posterior to pelvic-fin origin; free rear tip partly overlapping pelvic-fin anterior margin.

Head pronounced, deep, short and relatively narrow; projecting well anterior to pectoral-fin origins; subquadrangular in cross-section at pectoral-fin origin; cranial region of head broadly rounded in dorsoventral view; chondrocranium pronounced above eyes and spiracles; snout abruptly convex anterior of eyes, becoming deeply concave at origin of rostral lobe; slightly convex ventrally; ventral head length 26.0–33.5% DW, 1.46–2.23 times width at pectoral-fin origins, 2.96–6.36 times preorbital length (horizontal), 2.39–3.39 times interorbital width; preoral snout length 0.99–2.30 times mouth width, 1.73–2.99 times internarial width, 0.50–0.99 times distance between first gill slits; head width at pectoral-fin origin 14.8–17.8% DW, 1.58–1.93 times its height. Rostral lobe fleshy, long (very long in adult males); narrowly parabolic in dorsoventral view with a narrowly pointed apex; narrowly pointed in lateral view; its length 3.6–9.4% DW, 3.57–7.28 in head length, its width 1.38–1.98 in head width at pectoral-fin origin.

Interorbital space moderately broad, convex but with a broad medial depression, without ridges, denticles or thorns; interorbital width 9.2–11.0% DW, 1.72–2.37 times orbit length, 0.63–0.81 times head width at mid-eye. Eyes small, subcircular, very slightly ventrolateral on head; orbit level or only slightly elevated above dorsal head profile, diameter 2.12–3.08 in spiracle length, 5.84–8.78 in head width at pectoral-fin origin. Spiracles large, suboval to elliptical, situated dorsolaterally posterior to orbit and above pectoral-fin origin, more visible dorsally than laterally; margins without any protuberances or folds; length 4.8–6.8% DW, 2.08–3.75 times width.

Nostril narrowly suboval, immediately preceded by a broad, shallow, fleshy depression bordering anterolateral margin of the nasal curtain; anterior nasal fold thin, membranous, internal; deep oronasal groove present; internarial space 1.26–2.25 in prenasal length, 1.18–2.28 times nostril length. Nasal curtain large, elongate, lobate, width 1.32–1.94 times length; lateral margin concave, smooth edged; posterior margin divided by deep medial notch, bordered by a long, curtain-like fringe, not following contour of lower jaw; posterior margin of each lobe convex with apices narrowly rounded; most of surface finely papillate, covered with minute pores centrally; apex and posterolateral margin recessible within oronasal groove.

Mouth moderate-sized, transverse, located ventrally, width 6.5–8.9% DW, 0.44–1.01 times preoral length, 1.92–2.63 in head width at pectoral-fin origin; not protrusible, anterior teeth of lower jaw visible when mouth closed; buccal region intricately papillate; skin on chin and at margin of lower jaw fleshy, strongly furrowed, papillate, indented slightly at symphysis. Teeth in a single row in each jaw, coalesced to form plates; about 6 narrow, almost straight teeth in upper jaw, tooth plate well inside palate, its length about half its width (based on CSIRO H 4426–14); about 13 narrow, chevron-shaped teeth in lower jaw, tooth plate protruding distally, its length more than twice its width, its width about two thirds mouth width (based on CSIRO H 4426–14); roof of mouth with 2 rows of oral papillae, those in outer row slightly larger than those of inner row; floor of mouth near lingual margin of lower tooth plate with lunate fringe of about 16 variably shaped (usually pointed), irregular oral papillae. Gill openings small, elongated S-shaped, forming a weakly fringed lobe laterally; length of first gill slit 0.95–1.70 times length of fifth gill slit, 2.36–4.61 in mouth width; distance between first gill slits 2.86–3.95 times internarial space, 0.45–0.64 times ventral head length; distance between fifth gill slits 1.78–2.45 times internarial distance, 0.45–0.64 times ventral head length.

Pelvic fins moderately large, slender, subquadrangular, anterior margin slightly concave to almost straight, apex moderately angular, posterior margin moderately convex, free rear tip broadly rounded, inner margin slightly convex; extending well beyond pectoral-fin free tips; pelvic-fin length 14.3–18.7% DW, 1.12–1.74 times width across fin bases, inner margin 9.0–13.3% DW. Claspers of adult male (MNHN A7949) relatively short, outer length 6.4% DW.

Dorsal fin small, strongly raked, its origin posterior to pelvic-fin insertions by about half to two-thirds its fin base; anterior margin almost straight; apex broadly rounded, posterior to insertion of fin; posterior margin convex to nearly straight; free rear tip subangular, inner margin very short, nearly straight; predorsal length 1.46–1.80 in disc width, fin length 4.7–7.8% DW, height 0.35–0.67 times its length, inner margin 2.77–10.4 in fin length.

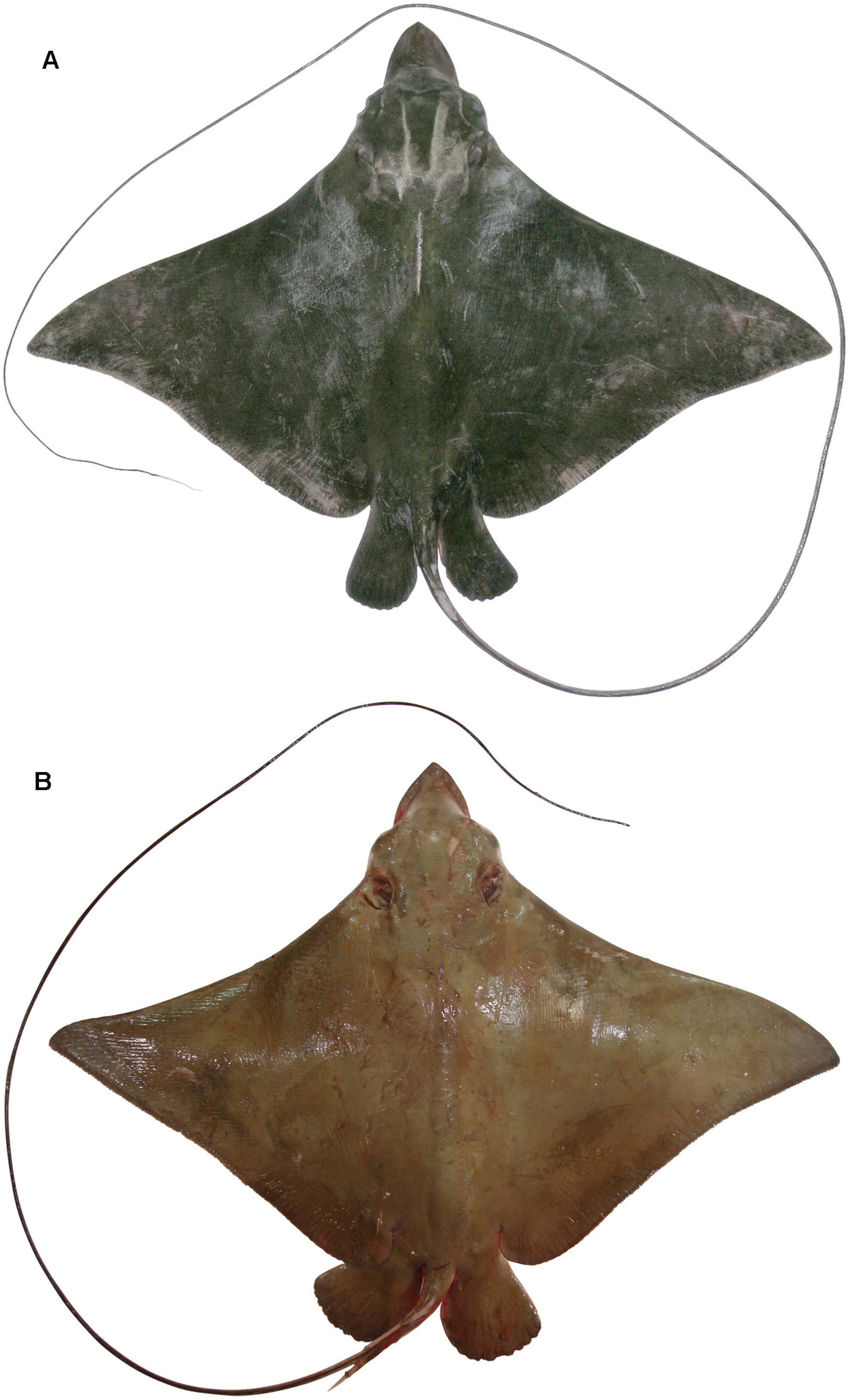

FIGURE 2. Dorsal view of *Aetobatus flagellum*. A. CSIRO H 6662–03 (immature male 346 mm DW); B. not retained fresh specimen from Kuwait (female ~500 mm DW).

Tail very long, slender, whip-like, its length (from cloaca origin) 1.22–2.81 times disc width; tapering gradually at base to stinging spine, and gradually becoming more whip-like beyond sting; base moderately compressed, suboval in cross section at pelvic-fin insertion, tail width at pelvic insertion 0.73–1.20 times height; almost rhomboidal in cross section near origin of stinging spine, width 0.59–1.36 times height at first spine origin; no skin folds present; a weak naked groove on dorsal surface of tail immediately posterior to base of stinging-spine(s), almost fully housing spines. Stinging spines 0–2, very elongate, slender, moderately broad-based, strongly tapered, almost fully serrated laterally; distance from sting base to pectoral-fin insertion 10.4–14.8% DW; longest stinging spine 9.4–16.2% DW, 1.86–3.44 times dorsal-fin length.

Vertebral centra total (including synarcual) 85–91 (n=7); total (excluding synarcual) 80–87 (n=7); monospondylous (including synarcual) 33–42 (n=8); monospondylous (excluding synarcual) 29–38 (n=8); pre-dorsal diplospondylous 13–29 (n=4); post-dorsal diplospondylous 27–34 (n=3). Total pectoral-fin radials (excluding propterygial radials anterior of eyes) 89–96 (n=7); propterygium (anterior of eyes) 13*–16*, propterygium (posterior of eyes) 10–14, mesopterygium 27–33, metapterygium 48–54. Pelvic-fin radials: 1 (4–6 fused elements) + 14–16 (n=7).

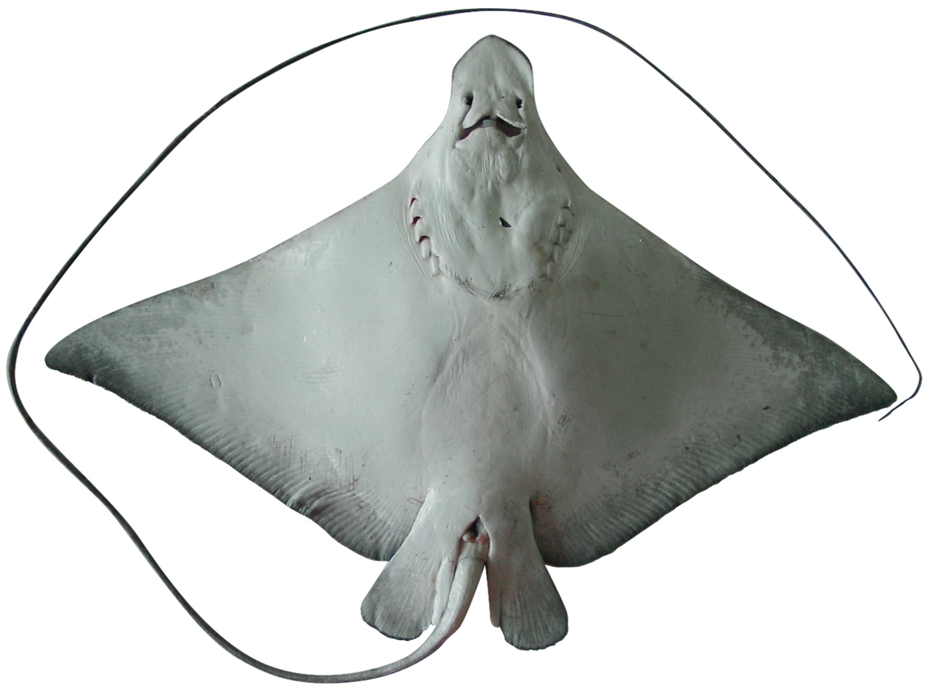

FIGURE 3. Ventral view of *Aetobatus flagellum*, CSIRO H 6134–01 (subadult male 431 mm DW).

Colour (when fresh). Dorsal surface uniformly brownish (sometimes greenish brown), without distinct markings; eye bluish black; dark (dorsal) and pale (ventral) surfaces well demarcated (waterline) at pectoral-fin origin at junction with head; waterline extending anteriorly to mid eye and onto forehead; dark dorsal surface on rostral lobe similar, contrasted with its paler ventral surface and posteriorly with pale mid-snout; tail uniform greyish brown. Ventral surface mostly whitish; broad brownish margin along most of disc, junction between brown margin and whitish ventral colour strongly mottled, broadest on posterior margin, narrowest anteriorly; distal third of pelvic fins brownish; rostral lobe mostly whitish, anteriormost margin narrowly brownish.

Size. The male and female specimens of *A. flagellum* measured in this study ranged in size from 233–543 and 243–578 mm DW, respectively. Two male specimens of 431 and 446 mm DW were adolescent, and one specimen of 543 mm DW was mature. Moore *et al.* (2012) reported 36 individuals from the Persian Gulf with males and females ranging from 277–580 and 330–746 mm DW, respectively; males mature by ~500 mm DW. Birth size unknown; smallest free-swimming individual examined was 233 mm DW. Specimens of up to 900 mm DW have been recorded from northern Kuwait (J. Bishop, Kuwait Institute for Scientific Research, unpubl. data). Sujatha (2002) recorded two specimens off Visakhapatnam in northeastern India, which were 790 and 830 mm DW, but no sex was given. A single female of 746 mm DW (not retained), was mature and had functional, but empty, uteri.

FIGURE 4. Ventral view of the head of *Aetobatus flagellum*, CSIRO H 6134–01 (subadult male 431 mm DW).

Distribution. Patchily distributed in the Indo–West Pacific; known from the Western Indian Ocean, from Kuwait in the Persian Gulf to Pakistan and India; and the Eastern Indian Ocean, from India and Sri Lanka to Indonesia (Kalimantan) and Malaysia (Sarawak). Not recorded from the east coast of South Africa (S. Dudley, KwaZulu-Natal Sharks Board, pers. comm. July 2009), Madagascar (A.J. Cooke, Blue Ventures, pers. comm.; Robinson & Sauer, 2013), Oman (Randall, 1995; Henderson & Reeve, 2011) nor the southern Persian Gulf (Moore *et al*., 2012; A. Moore unpubl. data). Reported presence in the Red Sea (Bonfil & Abdallah, 2004) was not based on records (R. Bonfil, pers. comm.) and requires confirmation, as it has not been reported previously from this region (Gohar & Mazhar, 1964). The Red Sea records are possibly due to its inclusion (mistakenly) as a synonym of *A. narinari* in species lists for the Red Sea (e.g. Fowler, 1956; Dor, 1984). Compagno & Last (1999) mentioned that records of *A. flagellum* from Hawaii and the Eastern Atlantic require confirmation. During this study, no specimens or accurate records of this species from these two regions were found and experts on the chondrichthyans faunas of Hawaii (J. Randall, BPBM, pers. comm. July 2009) and West Africa (B. Serét, pers. comm. March 2009) had no records. Records of this species from southern China require validation.

Discussion

Comparison with other species

The plain dorsal colouration of *Aetobatus flagellum* readily distinguishes it from members of the *A. narinari* complex, including the sympatric *A. ocellatus*, which has prominent pale bluish to whitish spots on the dorsal surface. Although members of this complex have a highly variable pattern of white spotting on the dorsal surface, they almost always have some white spots. Sometimes they can be mostly plain and with only a small number of white spots on the posterior margin of the disc. The dorsal colouration of *A. flagellum* is brownish compared to the sympatric *A. ocellatus* which is usually greenish grey to blackish.

Aetobatus flagellum is the smallest member of the genus attaining ~900 mm DW, with males and females mature by at least 500 and 746 mm DW, respectively. In comparison, members of the *A. narinari* complex are much larger. For example, *A. ocellatus* attains up to 3000 mm DW with males and females maturing at about 1000 and 2140 mm DW, respectively (White *et al.*, 2010). The *Aetobatus* sp. from the Northwest Pacific (see discussion below) is also a larger species attaining up to 1500 mm DW, with one male from Vietnam mature at 836 mm DW (www.tapewormdb.uconn.edu).

The rostral lobe is typically longer in *A. flagellum* than in *A. ocellatus* or *A. narinari*, rostral lobe length 3.6–9.4 (mean 7.0)% DW vs. 2.9–5.3 (mean 4.5) and 4.7–6.0 (mean 5.2)% DW, respectively (White *et al.*, 2010). This is most obvious in adult males of *A. flagellum* which have a much longer rostral length than females and immature males (see intraspecific variation discussion below). Although Last & Compagno (1999) stated that *A. flagellum* has a more narrowly tapering and acute snout compared to *A. narinari* (= *A. ocellatus*), snout shape varied greatly amongst the specimens examined. Thus, while this character is often useful, particularly in adult males, it should not be used as a diagnostic character.

The position of the dorsal fin appears to be a useful character in distinguishing *A. flagellum* from *A. ocellatus*. In the former species, the dorsal-fin origin is about level with or slightly behind the pelvic-fin insertions vs. posterior to pelvic-fin insertions by about half its fin base in the latter species. The lower tooth band also appears to be wider in *A. flagellum* (about two thirds mouth width) than in *A. ocellatus* and *A.* sp. (about half width of mouth).

Aetobatus flagellum has fewer vertebrae than *A. ocellatus*, i.e. total centra (excluding synarcuals) 80–87 (n=7) vs. 94–97 (n=3, White *et al.*, 2010). It also has fewer pectoral-fin radials than *A. ocellatus*, i.e. total (excluding propterygial radials anterior of eyes) radials 89–96 (n=8) vs. 102*–116 (n=3), although this is only based on a small number of *A. ocellatus* individuals. The stinging spine of *A. flagellum* appears to be slightly longer than those of *A. ocellatus* when intact, i.e. longest spine length 9.2–10.6 (mean 9.7, n=10) vs. 9.4–16.2 (mean 12.5)% DW. However, there is overlap in these measurements between these two species and therefore would not be a useful field character.

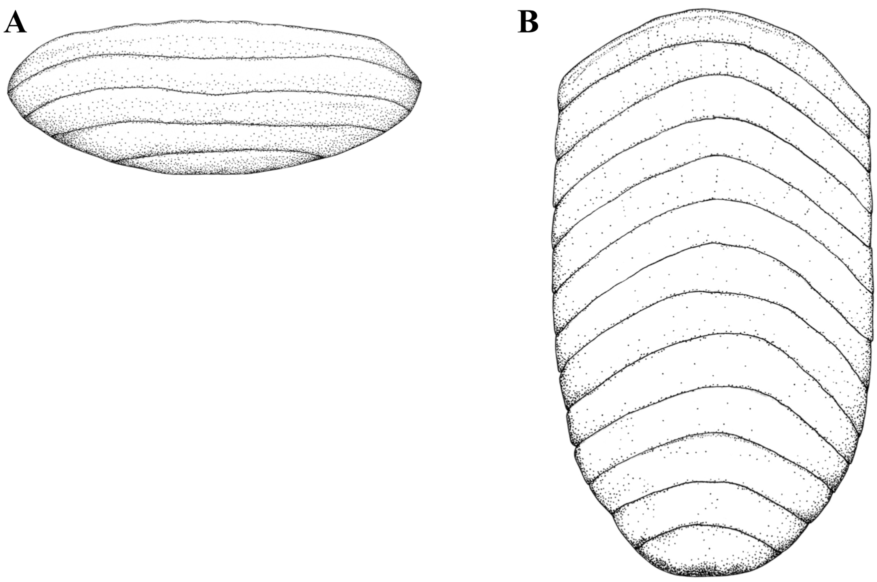

FIGURE 5. Illustration of the tooth plates of *Aetobatus flagellum* (CSIRO H 4426–14, subadult male 446 mm DW). A. upper; B. lower. Drawings by Lindsay Marshall.

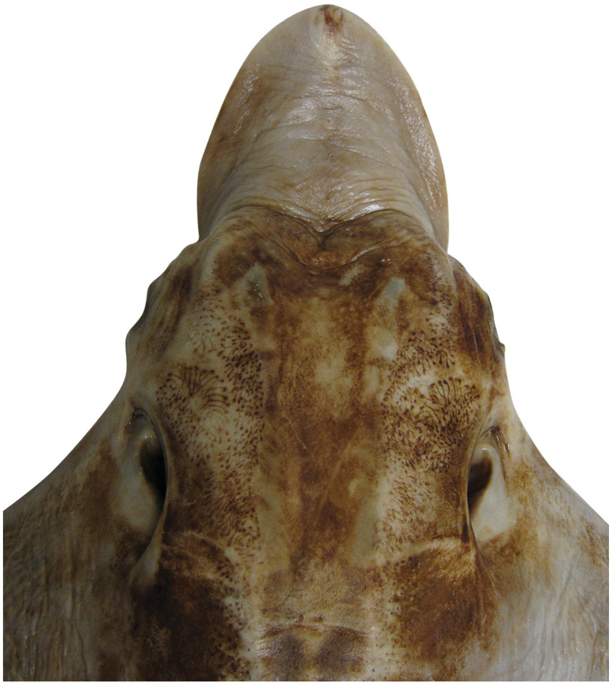

FIGURE 6. Dorsal view of the head of *Aetobatus flagellum*, MNHN A-7949 (adult male 543 mm DW).

Intraspecific variation

The rostral lobe of *Aetobatus flagellum* is much longer in adult males than in juvenile males and females, i.e. rostral length 9.4% DW in an adult male (Fig. 6) vs. 6.1–7.7 in subadult and juvenile males and 4.9–7.6% DW in females. The key characteristic currently used to distinguish this species from members of the *A. narinari* complex, apart from the dorsal colouration, is its very long snout. Thus, it is not surprising that these two species have been misidentified in the past given that snout length is a sexually dimorphic characteristic. While the white-spotting on the dorsal surface is a key characteristic distinguishing members of the *A. narinari* complex from *A. flagellum*, this colour pattern varies greatly even within one region with some specimens having plain or almost plain discs. Large adults of *A. narinari* (incl. *A. ocellatus*) often have very long snouts, which would also add to the confusion between these species (Last & Compagno, 1999).

Distribution and habitat preferences

Data from several surveys indicate that *A. flagellum* is uncommon where it occurs, and its description as "apparently rare" from a time before major intensification of inshore fisheries (Annandale, 1909) may suggest that is a naturally scarce species.

In a major survey of fish landing sites in eastern Indonesia between 2001 and 2006, *A. flagellum* comprised less than 0.1% of more than 28,000 batoids recorded (White & Dharmadi, 2007). Additional surveys of Indonesian fish landing sites between 2006 and 2007 by the senior author did not yield any more specimens of *A. flagellum*. The individuals of *A. flagellum* recorded from Indonesia were collected from fish markets in Jakarta and were part of the landings of gill net fishers operating off southern Kalimantan, an area with many large rivers and estuarine habitats. In a large-scale survey of shark and ray landings throughout all of Borneo in 2002–2004 (Last *et al.*, 2010), a single specimen of *A. flagellum* was recorded from Sukanabanung in West Kalimantan (01°48'12.90" S, 109°57'30.00" E). This site is strongly influenced by a major river system and the coastal waters are likely to be brackish for at least part of the year. No specimens were recorded from Malaysian Borneo during numerous surveys of fish landing sites and this species was also not treated in Yano *et al.*'s (2005) *Sharks and Rays of Malaysia and Brunei Darussalam.* Specimens examined from off India were collected from the Coromandel and Malabar coasts of southern India, both areas strongly influence by large river outflows (Talwar & Jhingran, 1991) Along the Iranian coast, Blegvad (1944) recorded four specimens of *A. flagellum* (as *A. narinari*) in January–April 1937 and 1938, equivalent to only 0.35% of batoid individuals recorded. Similarly, Vossoughi & Vosoughi (1999) recorded only four *A. flagellum* individuals (~1% of 366 batoids) from off the Hormuz coast of Iran (easternmost

Persian Gulf). In comparison, *A. flagellum* was relatively abundant in fish landing surveys in Kuwait in April 2008 and April 2011 (from vessels fishing in estuarine-influenced northern Kuwait waters), comprising 4.0 and 8.3%, respectively, of batoids (Moore *et al*., 2012). Furthermore, *A. flagellum* was the most abundant elasmobranch recorded in surveys in the estuarine system around Boubiyan Island, in northernmost Kuwait waters (J. Bishop, Kuwait Institute for Scientific Research, unpublished data).

The apparent strong association of *A. flagellum* with tropical and subtropical estuaries adds to the conservation concern of this species, as this habitat faces a multitude of threats (e.g. Blaber, 2002; Al-Yamani *et al*., 2007). There is no information available on population interconnectivity in this species, but if genetic exchange between estuary populations is limited then the species may be at risk of localised depletion. *Aetobatus flagellum* is caught only as a bycatch and they are either discarded or sold as low-value food, at least in Indonesia and the Persian/Arabian Gulf (White *et al*. 2006; Moore pers. obs.).

Northwest Pacific *A. flagellum* records

Northwest Pacific records of *Aetobatus flagellum* include from Goto Islands, the Seto Inland Sea, Wakayam, Shizuoka and Kyushu Island in southern Japan (Yamada & Miya, 1989; Nakabo *et al.*, 2001; Yamaguchi *et al.*, 2005; Kamei & Kayano, 2009) and the Japan Sea from off Japan (Suzuki & Hosokawa, 1994) and from off Hupo, Uljin in South Korea (Oh *et al.*, 2006). The identification of these eagle rays as *A. flagellum* is largely based on the fact they have a plain disc without white spots and a relatively long snout. However, the maximum sizes recorded for females and males of this species, i.e. 1500 and 1000 mm DW respectively, is far larger than the maximum sizes known for *A. flagellum* in other regions, i.e. <900 mm DW.

Oh *et al.* (2006) provided excellent images of their *A. flagellum* specimen from off South Korea and when compared with specimens from Indonesia, India and Kuwait, a number of striking differences are apparent. Firstly, the disc profile is very different with the anterior margin of the pectoral fins being mostly straight and slightly convex near the apex in the Korean specimen. In comparison, the Indonesian, Indian and Kuwait specimens have pectoral-fin anterior margins that are concave anteriorly and then convex near the apex. This gives the impression of the Korean specimen having a shorter head than the other specimens. Secondly, the rostral lobe is far narrower and shorter in the Korean specimen. Thirdly, the dorsal colouration of the Korean specimen is a purplish brown colour whilst the other specimens are all brownish in colour. There also may be a difference in the width of the lower tooth band which is about half the width of the mouth in the Korean specimen, compared to almost two thirds the width of the mouth in other specimens.

When the DNA barcode sequences of *A. flagellum* from Indonesia and Kuwait were compared with three sequences from Japan (n=2) and Korean waters (n=1) on GenBank, they were very distinct with an average divergence of 11.47% (Richards *et al.*, 2009; Yoon *et al.*, 2009; www.boldsystems.org). Interestingly, Naylor *et al.* (2012) recorded a species of *Aetobatus* from the Gulf of Tonkin off Vietnam whose sequences (ND2) were closest to, but genetically very distinct from, two *A. flagellum* samples from India and Indonesia. These authors referred to these 9 specimens as *Aetobatus* sp. and commented that it could represent an undescribed species. No specimens were retained but examination of images of these Vietnamese specimens (www.tapewormdb.uconn.edu) suggests it is conspecific with the Japanese and Korean specimens previously referred to as *A. flagellum*. Thus, the Northwest Pacific species previously called *A. flagellum* is likely an undescribed species with a distribution probably from the Gulf of Tonkin in Vietnam to Shizuoka in southern Japan, including the Sea of Japan off Korea and Japan. Previous records of *A. flagellum* from southern China need to be critically examined as these likely represent the undescribed species. This species has not been recorded from off Taiwan to date, which could be the result of misidentifications or a lack of suitable habitat.

Taxonomic investigation of this undescribed species is urgently required so that its conservation status can be addressed. This is particularly important given the fact that in Ariake Bay, Japan, it has been associated with reductions in bivalve stocks, which are the most important fishery resource in this area. Eagle rays in this area were shown to feed only on bivalves including the two main fishery species, the venerid *Ruditapes philippinarum* and the pinnid *Atrina pectinata* (Yamaguchi *et al.*, 2005). Since 2001, predator control programs were introduced to reduce the eagle ray populations with as many as 10,000 individuals culled per year (Yamaguchi *et al.*, 2005). Given the restricted distribution of this species compared to what was previously known, it is critical that this species is assessed as a distinct species of *Aetobatus*.

Comparative material

Aetobatus narinari: (5 specimens) BMNH 74.10.31.11, female 652 mm DW (1496 mm TL), Bermuda, North Atlantic; MNHN A7948, female 420 mm DW (1150 mm TL), Haiti, The Antilles, ca. 19° N, 73° W; MNHN A4053, juvenile male 600 mm DW (1632 mm TL), eastern Brazil, ~10° N, ~30° W; MNHN A7940 (2 juvenile males), 445 mm DW (1233 mm DW), 547 mm DW (tail tip damaged), Saint Barthelemy, French West Indies, 17°50' N, 62°49' W.

Aetobatus ocellatus: (14 specimens) CSIRO H 2490–01, juvenile male 456 mm DW (1330 mm TL), east of Brunswick Heads, New South Wales, Australia, 29°24' S, 153°23' E, 25–28 m, 08 Jun. 1990; CSIRO H 4426–19, female 498 mm DW (tail removed beyond dorsal fin), Muara Angke fish landing site, Jakarta, Indonesia, 17 Oct. 1995; CSIRO H 6131–02, juvenile male 577 mm DW (1528 mm TL), Muara Angke fish landing site, Jakarta, Indonesia, 06 Apr. 2001; IPMB 38.01.07 (head only), Kota Kinabalu fish market, Sabah, Malaysia, 04 May 2004; IPMB 38.01.08, juvenile male 704 mm DW, Kota Kinabalu fish market, Sabah, Malaysia, 30 May 2003; IPPS BO296, juvenile male 447 mm DW (1309 mm TL), Mukah, Sarawak, Malaysia, 02°53.52' N, 112°05.44' E, 22 May 2003; IPPS HBO2, female 740 mm DW (tail damaged), Sarawak, Malaysia, 2002; MNHN A8905 (holotype of *Raja quinqueaculeata*, dried dorsal fin and stinging spines only), Guam, ~13°30' N, ~145° E, ca. 1817–1820; MZB 18225 (neotype), juvenile male 477 mm DW (1422 mm TL), Muara Angke fish landing site, Jakarta, Indonesia, 20 May 2002; RMNH 33021, juvenile male 417 mm DW, Tami River, Papua New Guinea, 24 Jun. 1955; RMNH unregistered, female 482 mm DW (1322 mm TL), Halmahera Sea, Indonesia; SMEC 75, female 371 mm DW (tail missing), SMEC 76, juvenile male 352 mm DW (tail missing), Kota Kinabalu fish landing site, Sabah, Malaysia, Oct. 1996; SMEC 244, female 481 mm DW (1362 mm TL), Kota Kinabalu fish landing site, Sabah, Malaysia, 1997.

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