Simon Weigmann | **Hamburg**

Contribution to the taxonomy and distribution of eight ray species (Chondrichthyes, Batoidea) from coastal waters of Thailand

Abstract A collection of 24 rays from eight different species, obtained in 1993 from the marine shelf around Thailand, was examined in this study. The rays were determined, morphometrically and meristically analyzed, photographically documented and compared with relevant literature and available further collection material.

The tails of *Dasyatis akajei* were found to be distinctly longer than specified in literature. Compared to the references a larger maximal total length and morphometrical discrepancies for *Rhinobatos formosensis* as well as higher tooth row counts for *Himantura gerrardi* and *Rhynchobatus australiae* were detected. General taxonomical problems are discussed for the Rhynchobatidae.

For *Neotrygon kuhlii* a much wider depth distribution than previously known was found. Furthermore the known distribution area could be slightly extended for *Himantura walga* and strongly – by about 2500 km – for *Rhinobatos formosensis.*

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Introduction

About 600 of the more than 1200 globally known Chondrichthyes species are rays (Last & Stevens 2009), with the highest diversity of cartilaginous fish living in the East Indian Ocean (Fowler et al. 2005, White et al. 2006, Ebert & Winton 2010). Because of the substantially increased targeted fishery, the populations of many elasmobranch species declined over the last decades. Further reasons for the drop in many elasmobranch species are bycatch, habitat loss and biotope degradation in combination with the late attainment of sexual maturity, slow growth and low reproductive output of most species (Camhi et al. 1998, Stevens et al. 2000, Myers & Worm 2003, Fowler et al. 2005).

Thailand was the fifth important chondrichthyan fishing nation in the East Indian Ocean in 1997 with 5600 t officially landed (Vannuccini 1999). The examined specimens belong to the five Dasyatidae species *Dasyatis akajei*, *D. zugei*, *Himantura gerrardi*, *H. walga* and *Neotrygon kuhlii*, the Myliobatidae species *Aetomylaeus nichofii*, the Rhinobatidae species *Rhinobatos formosensis* and the Rhynchobatidae species *Rhynchobatus australiae.*

The Dasyatidae is by far the most speciose batoid family in Thai and adjacent waters with 31 species (Vidthayanon 2002). Its members are characterized by one or more tail stings (missing only in the genus *Urogymnus*), the reduction to tail folds or absence of their caudal fins and whip-like tails (Last & Compagno 1999). The second speciose family in this region is the family Myliobatidae with only seven species (Vidthayanon 2002). In its members the anterior part of the head is extended beyond the disc and the eyes are located laterally on the sides of the head. Furthermore the margin of the subrostral lobe is rounded and the floor of the mouth has fleshy papillae (Last & Stevens 2009). The Rhinobatidae with five and the Rhynchobatidae with four species in Thai and adjacent waters (Vidthayanon 2002) have a more or less shark-like body (Serena 2005), two well-developed and widely separated dorsal fins and no tail spine (Last & Stevens 2009). Furthermore the members of both families have a caudal fin, which has a well-developed ventral lobe in the family Rhynchobatidae and a not well-defined ventral lobe in the Rhinobatidae (Last & Stevens 2009).

Despite the numerous newly described elasmobranch species of the last years (e.g. Last et al. 2007, Last et al. 2008a, Last et al. 2008b, Last & Stevens 2009, Last et al. 2010), the biology and distribution of many species are still little known. In various cases the original descriptions of ray species are old and sketchy like those of Müller & Henle (1838–1841) and comprehensive revisions or redescriptions have only rarely been made (Last & Stevens 2009). In several cases the distinguishing features of very similar species from the same genus are not well-defined or based on outdated descriptions.

In order to make a contribution to the filling of these knowledge gaps 24 ray specimens from coastal waters of Thailand were examined. This study provides extensive morphometrical analyses for eight ray species for most of which such detailed morphometrics have not been published before. Additionally, tooth row, vertebral and fin ray counts are given for all specimens as well as detailed morphological descriptions and comparisons with relevant literature. Maps showing the distribution areas to the full extent as well as radiographs are presented here for the first time for several species. The uniquely thickened tails of adult female *Himantura walga* specimens are also pictured for the first time. Furthermore the depth distribution of *Neotrygon kuhlii* and the distribution areas of *Himantura walga* and *Rhinobatos formosensis* are extended.

Material and Methods

The examined batoids were collected by Matthias Stehmann during a Thailand expedition that took place from the 5th to the 11th December 1993. The specimens were collected from local fishermen in the four Thai harbors shown in the map in Fig. 1: Prachuap Khiri Khan (12°14'N 100°E), Chumphon (10°27'N 99°15'E), Pak Phanang (8°20'N 100°15'E) and Kantang (7°18'N 99°24'E). The map was generated using ArcMap™ 9.3.1 by ESRI® (ESRI 1999–2009) and based on the Global Relief Model ETOPO 1 of the National Geophysical Data Center (NOAA, Amante & Eakings 2009). The country borders were visualized by means of the shapefiles supplied by ESRI for the ArcExplorer-Java Edition for Education 2.3.2 (AEJEE, ESRI 1992–2007). Land below the sea level was

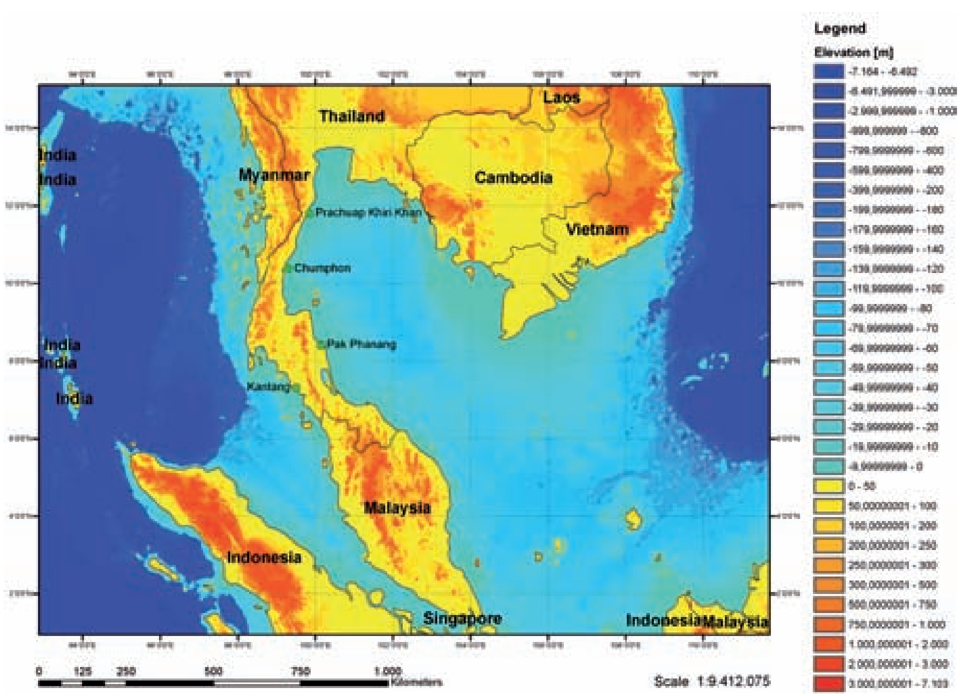


Figure 1

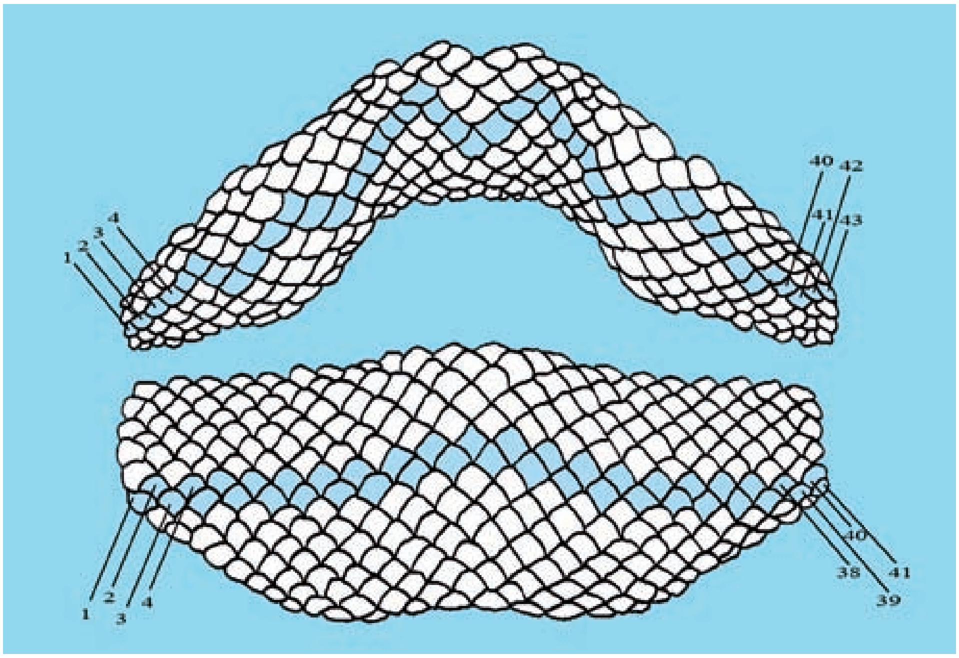


Figure 2

colorized in the color of the lowest land elevation class using Adobe® Photoshop® CS 4 (Adobe 1990–2008).

A total of 24 specimens was examined. All specimens were fixed in 4% formaldehyde solution soon after the catch and preserved in 70% ethanol afterwards.

With regard to *Himantura walga* further material from the ZMH fish collection was examined for comparative purposes.

Morphometrics and meristics were done following Bigelow & Schroeder (1953) with minor modifications unless otherwise stated. The tooth rows of the rays were counted in zigzag patterns as shown in Fig. 2 by means of a schematic painting of a sting ray jaw after Bigelow & Schroeder (1953), because the teeth of rays are arranged in a pavement pattern. This schematic jaw has 43 tooth rows in the upper and 41 rows in the lower jaw.

For the Rhinobatidae and Rhynchobatidae additional measurements were taken after Norman (1926) and Last et al. (2004). Unless otherwise indicated the photographs were taken with a Nikon D90 and a Nikkor 18–105 mm zoom lens and afterwards reworked using Adobe Photoshop CS4 (Adobe 1990–2008). Radiographs of all examined specimens were taken with a 1979 launched MG 101 X-ray equipment for radiography by Philips. They were used for verifying the tooth row counts and for taking internal meristics (vertebral and fin ray counts) of all specimens. The internal meristics were done following Krefft (1968) for the Myliobatiformes and after Compagno & Last (2008) for the Rhinobatiformes. Distribution maps are provided for all species with new distribution information or for which current distribution maps showing the distribution area to the full extend have not been available from other sources. The maps were generated using ArcMap 9.3.1 (ESRI 1999–2009) and based on the shapefiles supplied by ESRI for the ArcExplorer-Java Edition for Education 2.3.2 (AE-JEE, ESRI 1992–2007). The distribution areas and catch locations were drawn with Adobe Photoshop CS4 (Adobe 1990–2008).

Results

The 24 examined ray specimens represent eight different species from two orders, four families and six genera. Their classifications, numbers of individuals and catch locations are shown in Table 1.

Table 1 Classifications, numbers and locations of the examined specimens.

class	subclass	order	family	genus	species	number	harbor
Chondrichthyes							
	Elasmobranchii						
		Myliobatiformes					
			Dasyatidae				
				Dasyatis			
					akajei	2	Ch
					zugei	4	PK
				Himantura			
					gerrardi	2	Kt
					walga	6	PK
				Neotrygon			
					kuhlii	5	Kt
			Myliobatidae				
				Aetomylaeus			
					nichofii	1	Kt
		Rhinobatiformes					
			Rhinobatidae				
				Rhinobatos			
					formosensis	2	??
			Rhynchobatidae				
				Rhynchobatus			
					australiae	2	PP

The abbreviations of the harbors stand for Ch = Chumphon, Kt = Kantang, PK = Prachuap Khiri Khan, PP = Pak Phanang, ?? = exact Thai harbor unknown.

Typical characteristics which proved to be important for the determination are provided for all specimens as well as comparisons with relevant literature and – in the case of more complex determination procedures – differences to similar species. Furthermore comments about aberrations in the examined specimens from the descriptions in literature and possible mistakes or problems in the references including taxonomically problematic cases are given. These themes are not part of the conclusion chapter, but have been included directly in the results chapter to allow direct comparisons with the species descriptions. With the exception of the two specimens of *Rhynchobatus australiae*, which are pictured with three habitus photographs, two habitus photographs are shown for each of the examined specimens. Distribution maps are given for *Dasyatis akajei, D. zugei, Himantura gerrardi, H. walga and Rhinobatos formosensis* because no current maps illustrating the complete distribution areas of these species have been available. For distribution maps of the other examined species see for example Last & Stevens (2009). Tables with the measurements of all 24 analyzed specimens can be found in the appendix. A collection of sharks from the same expedition will be described by the author in a subsequent paper.

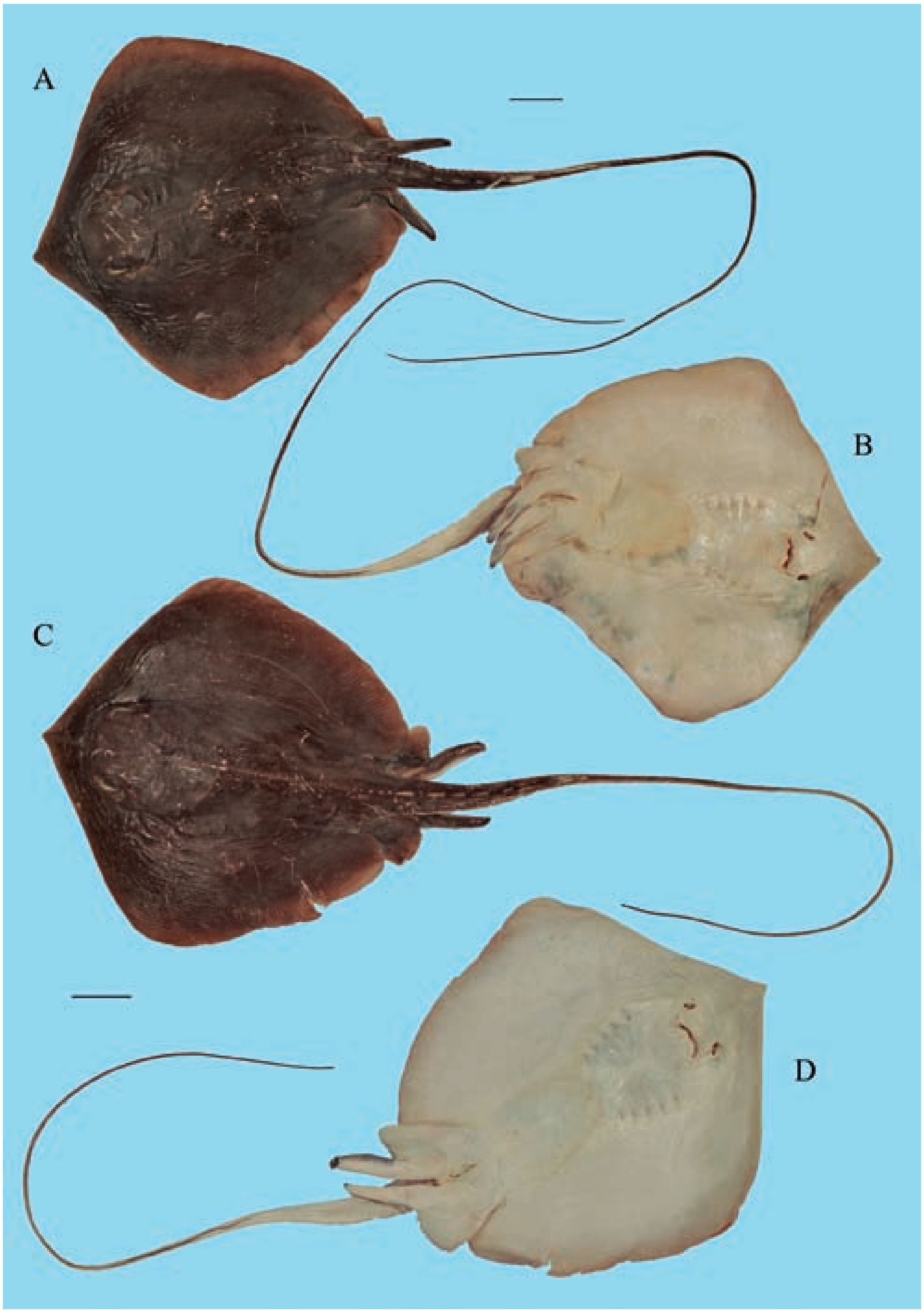
Dasyatis akajei (Müller & Henle, 1841)

The two specimens of *Dasyatis akajei* (ZMH 25685 and ZMH 25686) were caught by local fishermen in about 30 m depth in the Gulf of Thailand near Chumphon on the 6th December 1993. As described for this species by Last & Compagno (1999) they have a short snout, no dark transverse band through the eyes, their ventral skin fold terminates anterior to the tip of the undamaged tail, their dorsal surface lacks color patterns and their tail is not banded posterior to the sting (Fig. 3, A–D). Furthermore the undersurface of the disc and their pelvic fins are whitish with a broad yellowish brown margin (Fig. 3, B, D).

The two examined specimens differ from the similar species *Dasyatis bennettii* (Müller & Henle, 1841) in having a dorsal skin fold on their tail, which is not present in *D. bennettii.* Additionally both specimens have many minute tubercles around the dorsal median row of thorns as well as five (ZMH 25686, Fig. 3, A) to six (ZMH 25685, Fig. 3, C) large thorns on the tail anterior to the sting. *Dasyatis bennettii* in contrast has only few and small thorns anterior to the sting and no tubercles around the median row (Last & Compagno 1999).

In the similar species *Dasyatis fluviorum* Ogilby, 1908 and *D. parvonigra* Last & White, 2008a, which like *D. akajei* have a dorsal skin fold on their tail, the dorsal thorns are restricted to a median row of small thorns with no thorns on the tail (Last & Stevens 2009).

Both examined specimens of *Dasyatis akajei* differ from the references in having a tail that is more than two times longer than their disc width, while it is less than two

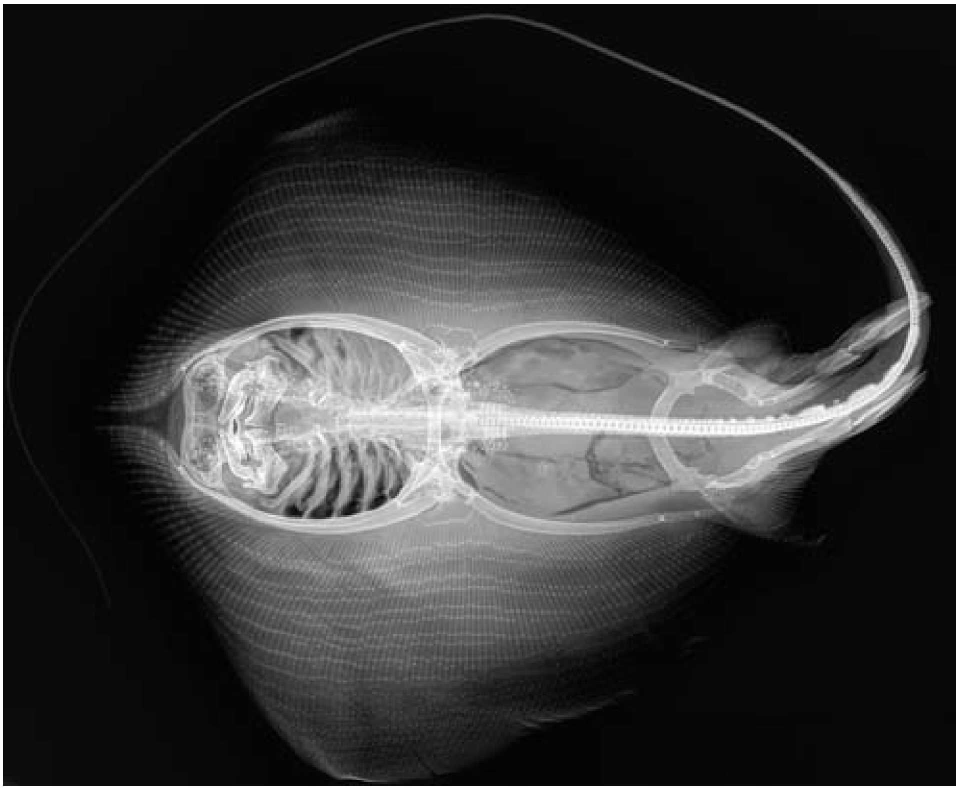


Figures 3

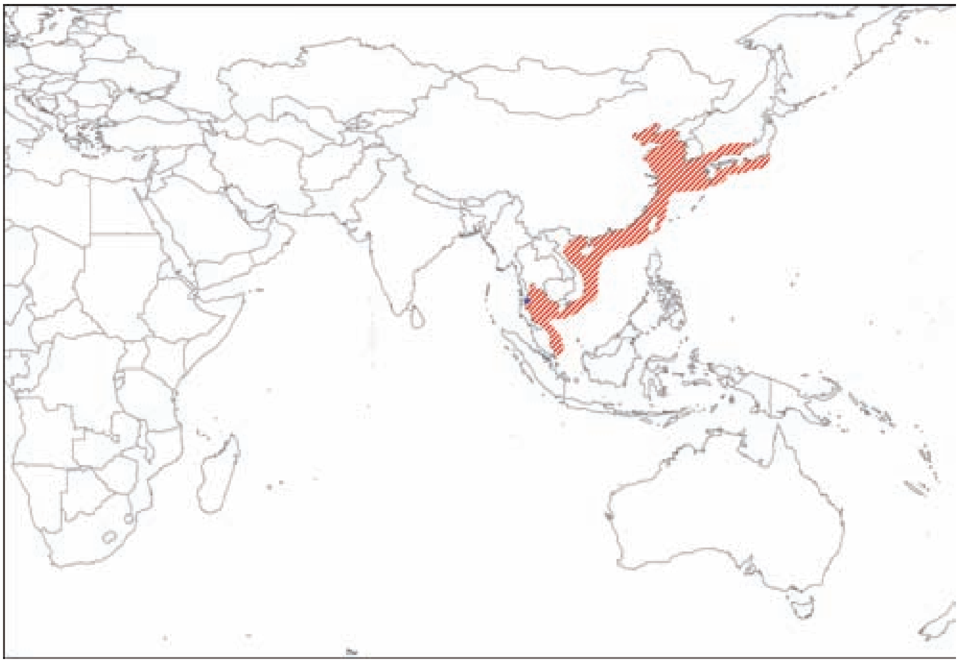
times longer following Last & Compagno (1999). However, they also mention that only little is known about *Dasyatis akajei* in general. Following Müller & Henle (1841) this character seems to be very variable as in the seven specimens examined by them the tail was between one quarter to two times longer than the body width. In the seven specimens analyzed by Müller & Henle (1841) it is most likely that at least in some of them the tails were partially broken and healed afterwards during their lifetimes. As this happens often in the whip-like tails of sting rays and is only hardly detectable in many cases, length measurements should always be utilized cautiously. Last & Stevens (2009), too, mentioned that length measurements are not always useful when describing the size of sting rays because of the often damaged whip-like tails. Further material would be necessary to do more comparisons of the tail length.

The specimen ZMH 25685 has 42 tooth rows in the upper and 53 in the lower jaw, specimen ZMH 25686 has 41 in the upper and 51 rows in the lower jaw.

The internal meristics are as follows: ZMH 25685: Vertebral centra anterior to the first sting: 97, total vertebral centra count: 118, monospondylous or pretransitional centra (from first complete centrum in synarcual to mono-diplospondyly transition): 37, diplospondylous centra: 81; pectoral fin rays (left/right): 111/111, ventral fin rays (left/right): 20/22 (excluding claspers). ZMH 25686 (Fig. 4): Vertebral centra anterior to the first sting: 104, total vertebral centra count: 119, monospondylous centra: 38, di-



Figures 4



Figures 5

plospondylous centra: 81; pectoral fin rays (left/right): 113/112, ventral fin rays (left/right): 23/23 (excluding claspers).

According to Last & Compagno (1999) *Dasyatis akajei* reaches a maximal disc width of at least 66 cm. Both in this study examined specimens already have – at disc widths of 35.5 cm (ZMH 25685) and 32.3 cm (ZMH 25686) – fully developed claspers (Fig. 3, A–D) and thus can be considered to be adult. Therefore this species probably does not grow much larger than 66cm disc width.

Following Last & Compagno (1999) *Dasyatis akajei* is distributed from East Thailand to South Japan.

Two habitus photographs of each of the specimens ZMH 25685 and ZMH 25686 are shown in Fig. 3 and a radiograph of specimen ZMH 25686 in Fig. 4. A distribution map for *Dasyatis akajei* is pictured in Fig. 5, in which the distribution area after Last & Compagno (1999) as well as the species dataset of the Global Biodiversity Information Facility (GBIF, 2010) is marked in red and white stripes and the catch location of specimens ZMH 25685 and ZMH 25686 as a blue spot. Their measurements can be found in Tables A1 and A2.

Dasyatis zugei (Müller & Henle, 1841)

The two male and two female specimens of *Dasyatis zugei* (ZMH 25689) were caught by local fishermen in the Gulf of Thailand near Prachuap Khiri Khan in about 50 m depth on the 5th December 1993. Following Last & Compagno (1999) they have – contrary to all other species of the family Dasyatidae in this region – an extremely elongated snout with the anterior margin of the disc being broadly concave. As described by Last & Compagno (1999) for *Dasyatis zugei* they have no dark transverse band through the eyes, their ventral skin fold terminates anterior to the tip of the undamaged tail, their dorsal surface lacks color patterns and their tail is not banded posterior to the sting (Figs. 6–7).

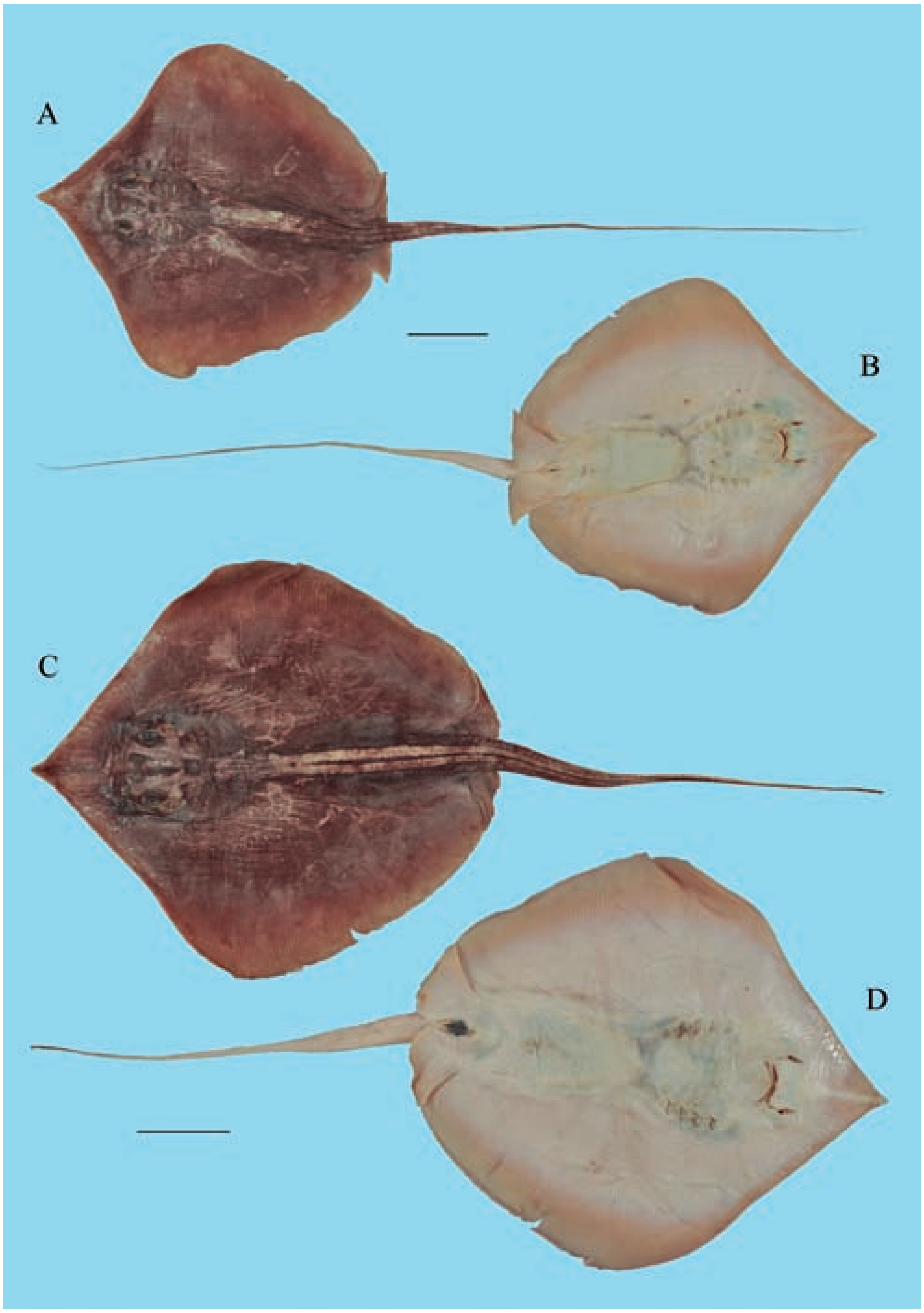
The small female with 210 mm disc width has 48 tooth rows in the upper and 45 in the lower jaw, the larger female with 233 mm disc width has 40 and 46 rows, the small male with 164 mm disc width has 41 and 43 and the larger male with 178 mm disc width has 45 and 41 tooth rows. Krefft (1961) mentions three juvenile specimens of *Dasyatis zugei* with 44 to 48 tooth rows in the upper and 45 to 52 rows in the lower jaw.

The internal meristics are as follows: Female, 210 mm disc width (Fig. 8): Vertebral centra anterior to the first sting: 85, total vertebral centra count: 95, monospondylous centra: 37, diplospondylous centra: 58; pectoral fin rays (left/right): 111/111, ventral fin rays (left/right): 20/20. Female, 233 mm disc width: Vertebral centra anterior to the first sting: 89, total vertebral centra count: 95, monospondylous centra: 34, diplospondylous centra: 61; pectoral fin rays (left/right): 113/113, ventral fin rays (left/right): 21/19. Male, 164 mm disc width: Vertebral centra anterior to the first sting: 85, total vertebral centra count: 94, monospondylous centra: 36, diplospondylous centra: 58; pectoral fin rays (left/right): 108/109, ventral fin rays (left/right): 16/16 (excluding claspers). Male, 178 mm disc width: Vertebral centra anterior to the first sting: 80, total vertebral centra count: 86, monospondylous centra: 32, diplospondylous centra: 54; pectoral fin rays (left/right): 94/101, ventral fin rays (left/right): 15/14 (excluding claspers).

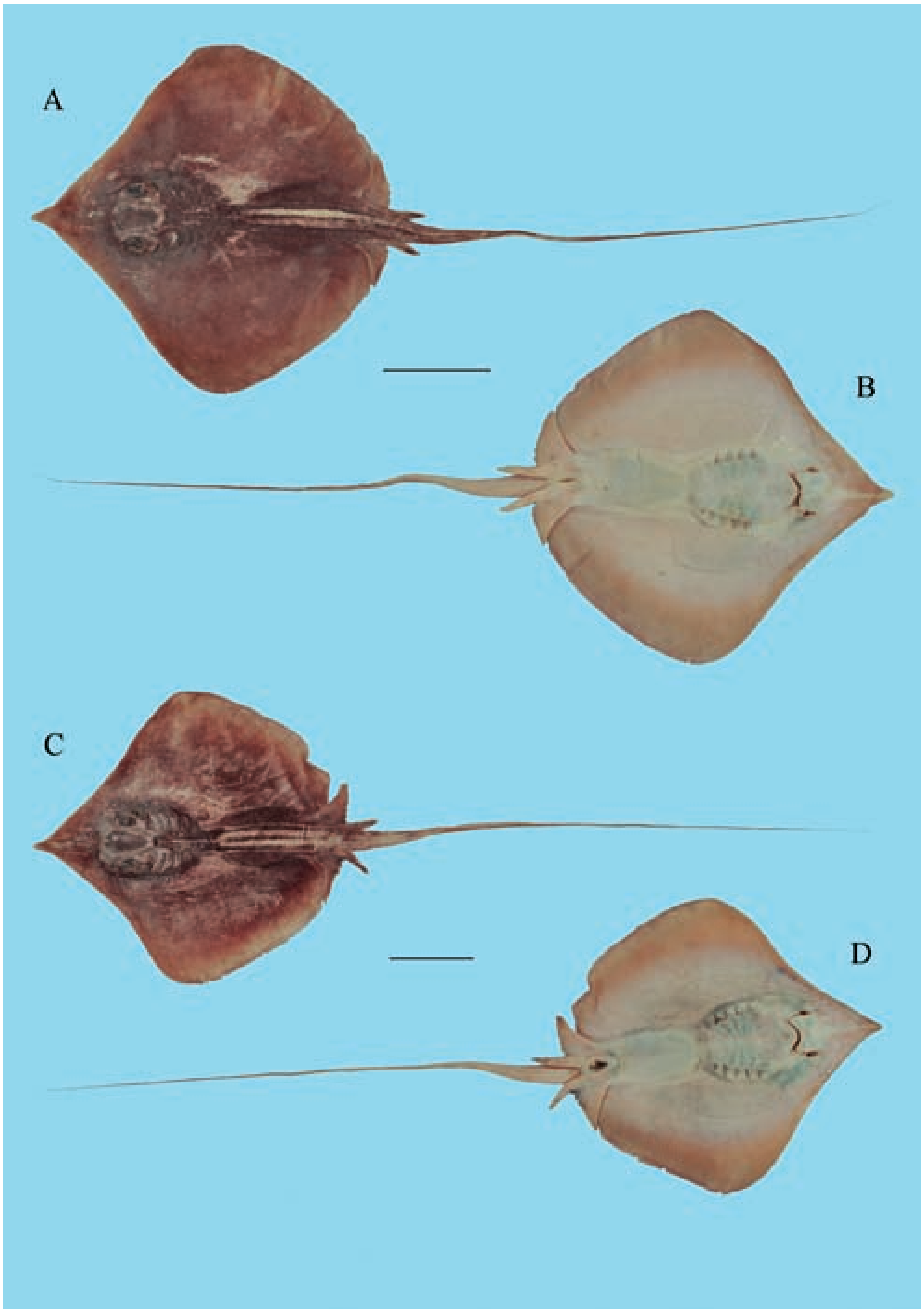
According to Last & Compagno (1999) *Dasyatis zugei* reaches a maximal disc width of at least 29 cm and the commercial width averages about 18 cm. For this reason the two females can be considered as large specimens. The already fully developed claspers of the only 16.4 cm and 17.8 cm wide males (Fig. 7, A–D) suggest the conclusion that this species does not grow much larger than 29 cm.

Although only little is known about the biology of *Dasyatis zugei*, which is distributed from India over Southeast Asia to South Japan, this species is taken in commercial quantities in the Gulf of Thailand (Last & Compagno 1999).

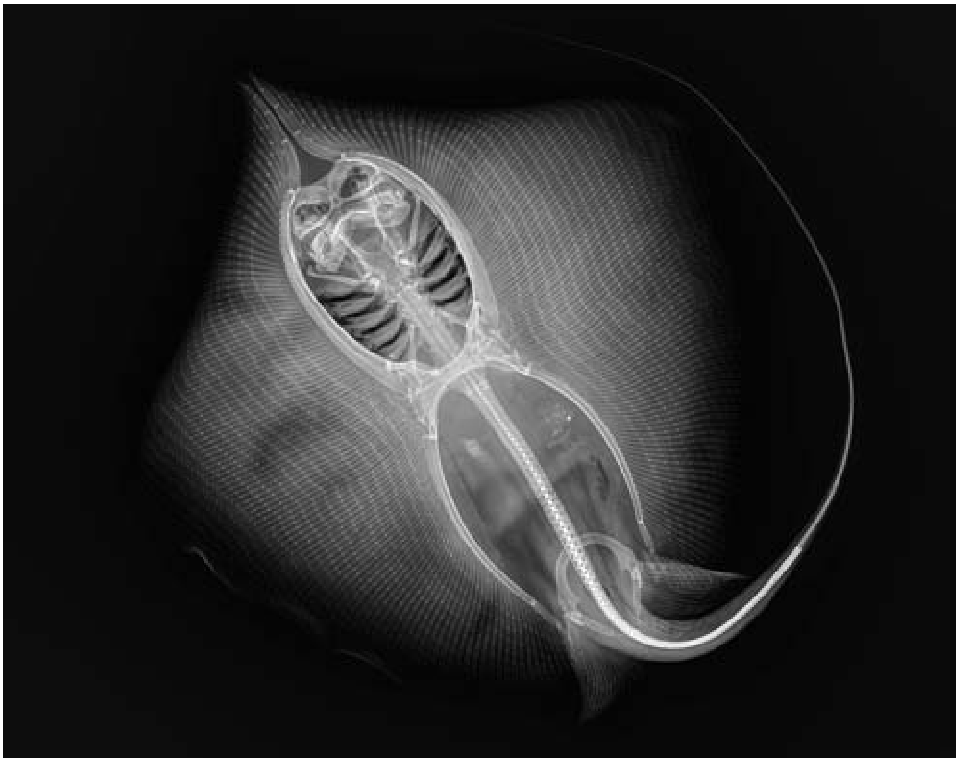
Two habitus photographs of each of the four specimens (ZMH 25689) are shown in Figs. 6 and 7 and a radiograph of the 210mm wide female in Fig. 8. A distribution map for *Dasyatis zugei* is pictured in Fig. 9, in which the distribution area after Last & Compagno (1999) as well as the species dataset of the Global Biodiversity Information Facility (GBIF, 2010) is marked in red and white stripes and the catch location of the four examined specimens as a blue spot. Their measurements can be found in Tables A3–A6.



Figures 6



Figures 7



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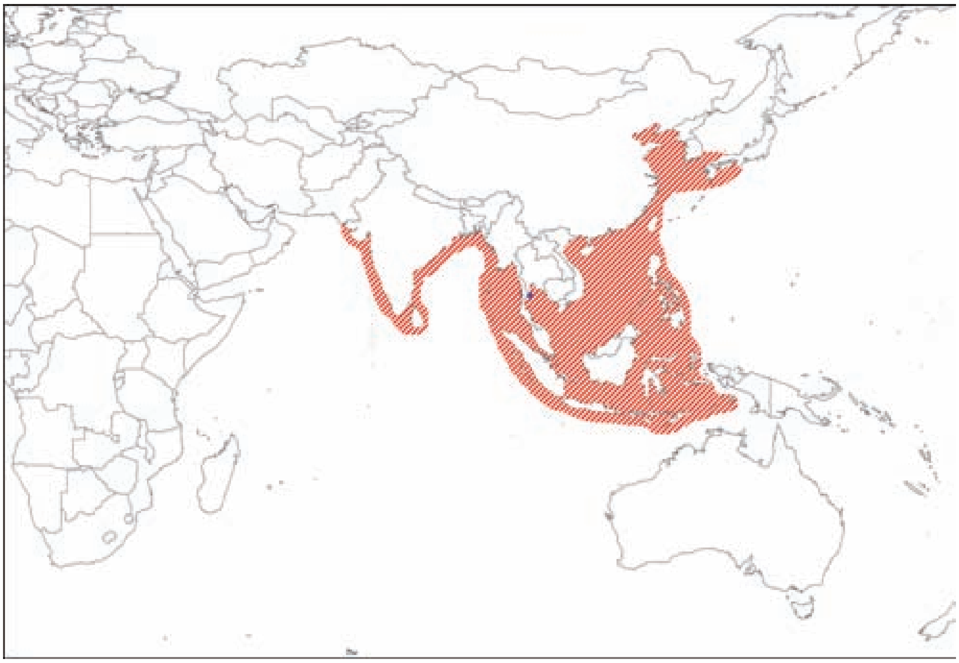


Figures 9

Himantura gerrardi (Gray, 1851)

The two specimens of *Himantura gerrardi* (ZMH 25691 and ZMH 25692) were caught by local fishermen in about 40 m depth in the East Andaman Sea near Kantang on the 8th December 1993. The most obvious morphological characters for the determination following Last & Compagno (1999) are a prominent greenish, pearl-like thorn dorsomedially, white spots on the upper surface and a very long and slender tail with alternating black and white bands on the upper half of the tail beyond the sting (Fig. 10, A–D). As described by Last & Compagno (1999) both specimens have no complex color patterns on the upper surface besides the white spots. In specimen ZMH 25691 the white spots are restricted to the posterior part of the disc, the tail base and the pelvic fins (Fig. 10, A), whereas they are spread almost over the whole dorsal surface, the tail base and the pelvic fins in specimen ZMH 25692 (Fig. 10, C).

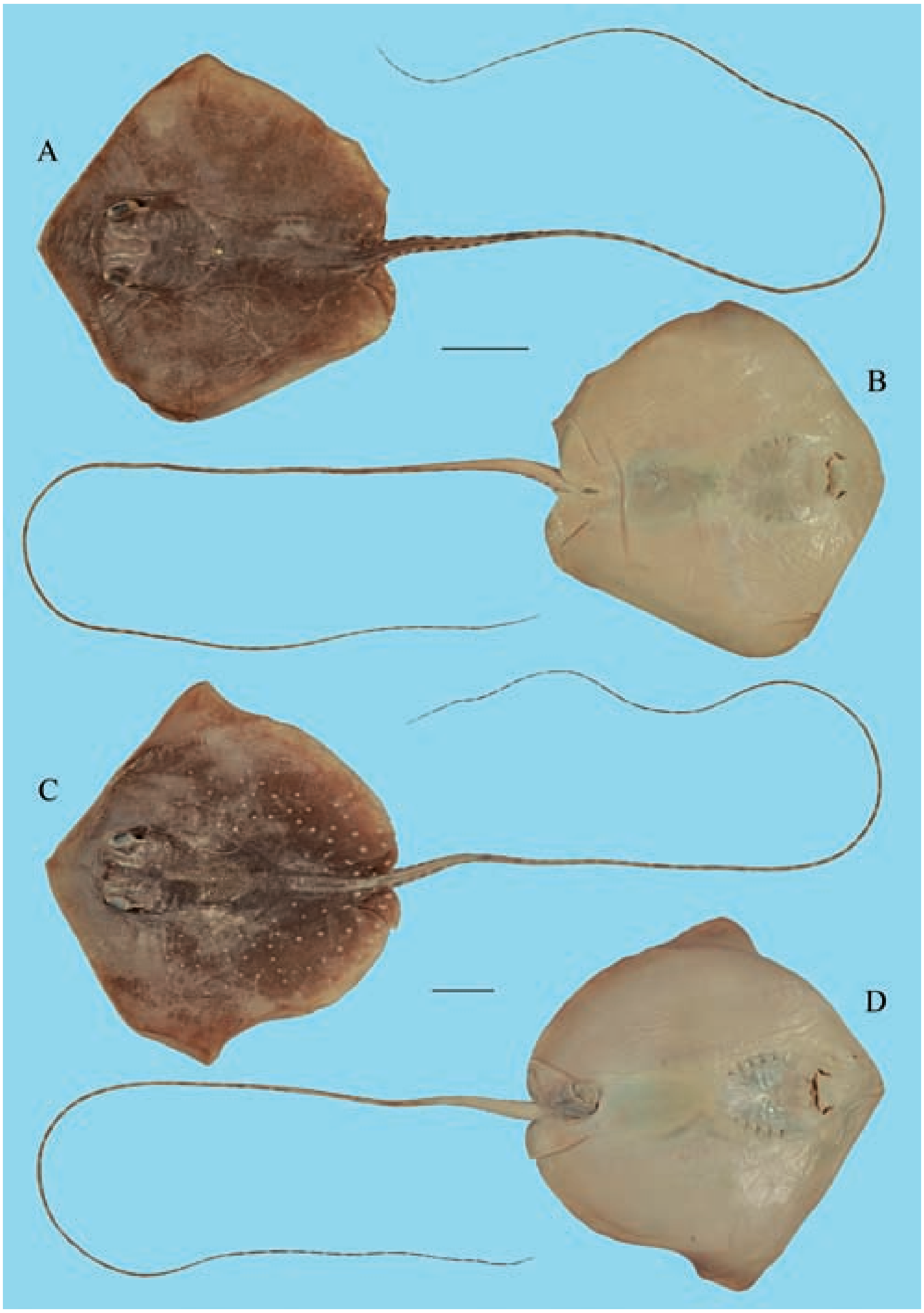
Specimen ZMH 25691 has 36 tooth rows in the upper and 44 in the lower jaw, exemplar ZMH 25692 has 40 and 50 tooth rows. Krefft (1961) mentions three juvenile specimens of *Himantura gerrardi* with 33 to 37 tooth rows in the upper and 36 to 38 rows in the lower jaw, whereas Fowler (1941) lists only 13 tooth rows for the upper and 23 rows for the lower jaw of this species. Krefft (1961) recounted the teeth of the specimen analyzed by Fowler (1941) and got out 30 tooth rows in the upper and 28 rows in the lower jaw. He also redetermined this specimen as *Himantura fai* instead of *H. gerrardi.*

The internal meristics are as follows: ZMH 25691 (Fig. 11): Vertebral centra anterior to the first sting: 118, total vertebral centra count: 118, monospondylous centra: 50, diplospondylous centra: 68; pectoral fin rays (left/right): 140/140, ventral fin rays (left/right): 23/23 (excluding claspers). ZMH 25692: Vertebral centra anterior to the first sting: 112, total vertebral centra count: 112, monospondylous centra: 51, diplospondylous centra: 61; pectoral fin rays (left/right): 139/139, ventral fin rays (left/right): 29/29. The free vertebral centra terminate far anterior to the first sting in both specimens of *Himantura gerrardi* (Fig. 11), whereas they terminate posterior to the sting in all other in this study examined species of stingray.

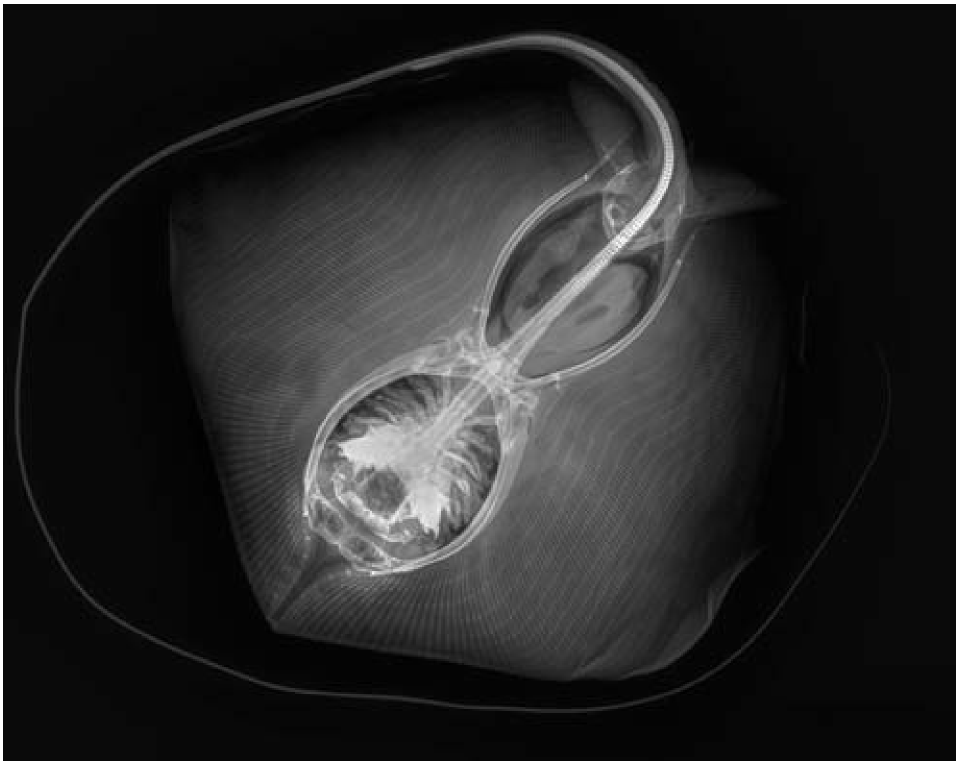
Compared to the maximal disc width of 90 cm (Last & Compagno 1999), both specimens are clearly juveniles with 22 cm (ZMH 25691) and 31.5 cm (ZMH 25692), which is supported by the not fully developed claspers of the male ZMH 25691 (Fig. 10, B).

According to Last & Compagno (1999) *Himantura gerrardi* lives on the continental shelf with the exact depth distribution still being unknown. It is the commercially most important sting ray species in its distribution area, which ranges from India over Southeast Asia to Papua New Guinea in the East and Taiwan in the North. Records from the East and Southeast African coast need to be verified (Last & Compagno 1999).

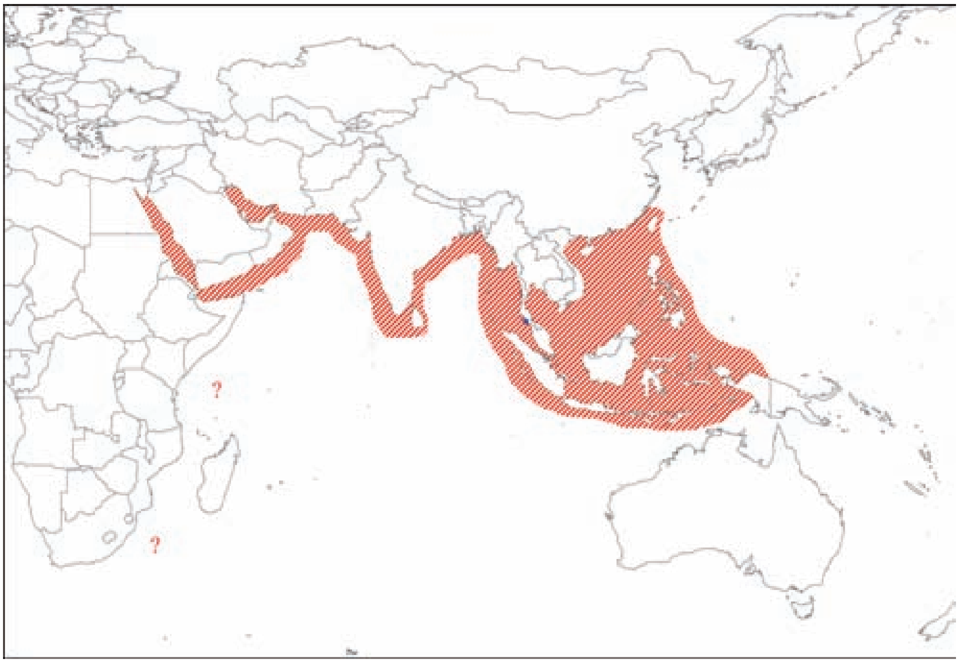
Two habitus photographs of each of the specimens ZMH 25691 and ZMH 25692



Figures 10



Figures 12



Figures 13

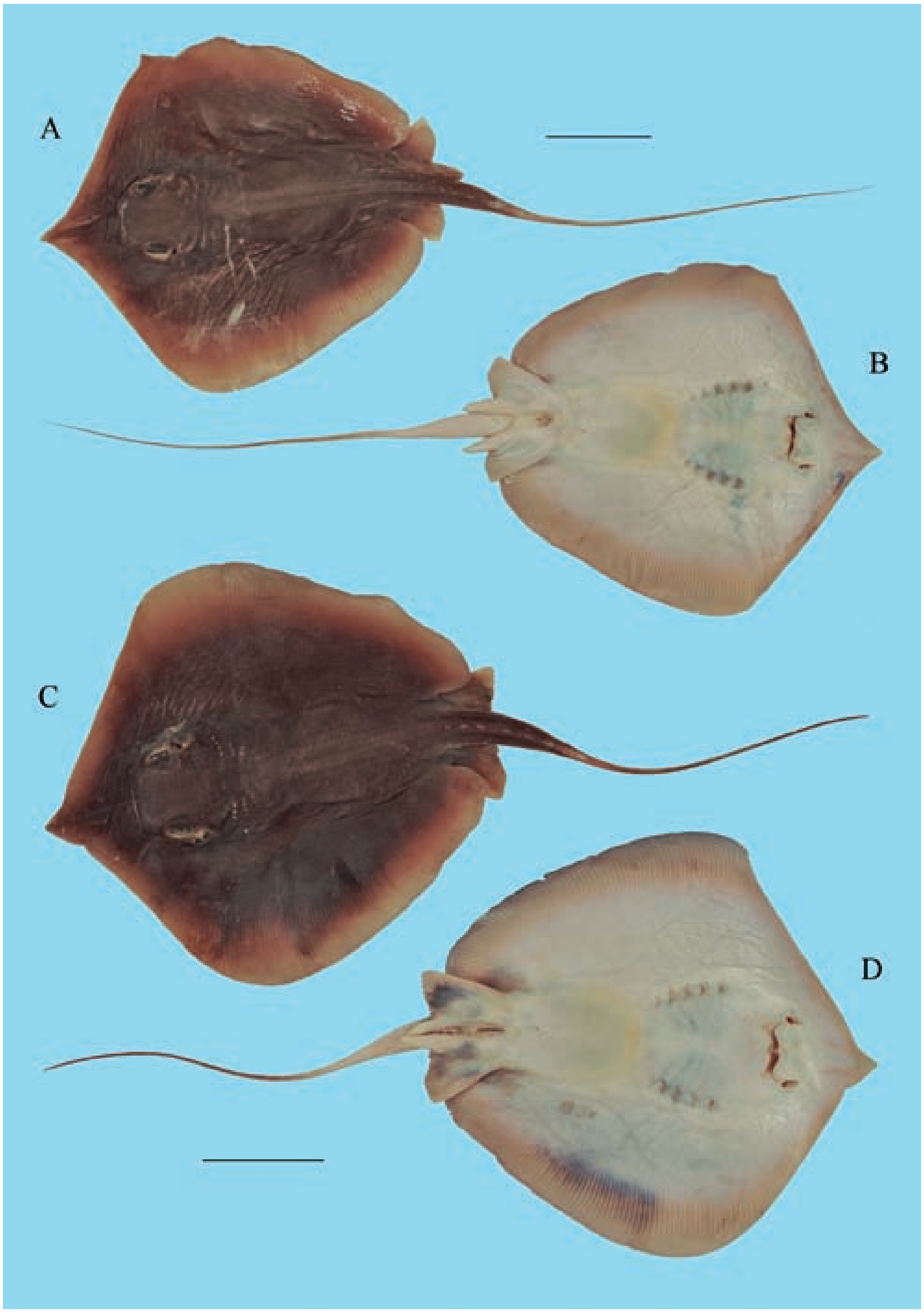
are shown in Fig. 10 and a radiograph of specimen ZMH 25691 in Fig. 11. A distribution map for *Himantura gerrardi* is pictured in Fig. 12, in which the distribution area after Last & Compagno (1999) as well as the species dataset of the Global Biodiversity Information Facility (GBIF, 2010) is marked in red and white stripes and the catch location of specimens ZMH 25691 and ZMH 25692 as a blue spot. Their measurements can be found in Tables A7 and A8.

Himantura walga (Müller & Henle, 1841)

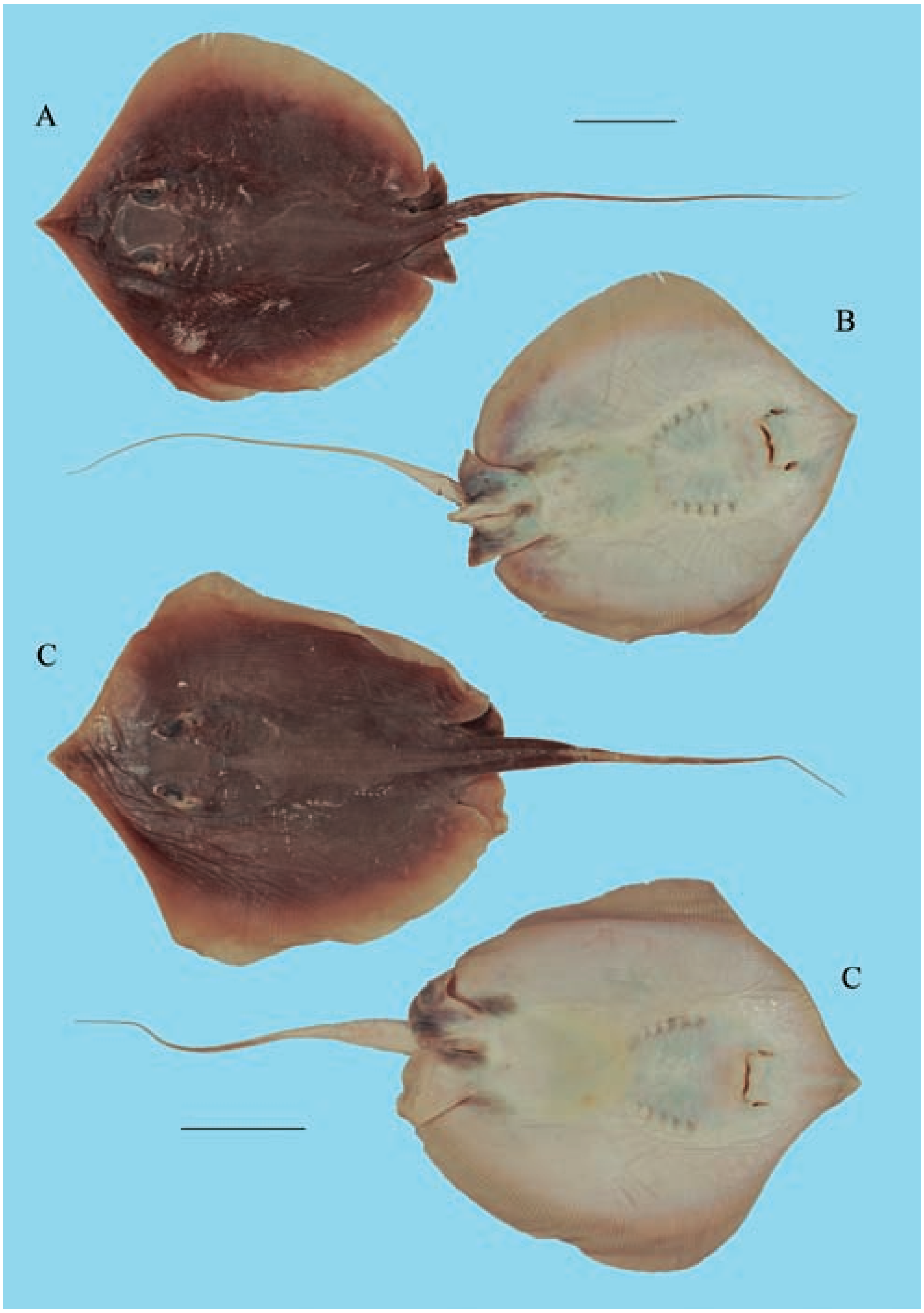
The three male and three female specimens of *Himantura walga* (ZMH 25690) were caught by local fishermen in the Gulf of Thailand near Prachuap Khiri Khan in about 50 m depth on the 5th December 1993. As described for this species by Last & Compagno (1999) all six specimens have a broad dense band of low, flat and heart-shaped denticles from just anterior to the orbit over the middle of the disc to the tail spine (Figs. 13–15, A, C). Furthermore they are small-sized, have an acute snout with a prominent tip, an almost oval disc, no cutaneous folds as well as a plain brownish upper and a uniformly whitish ventral surface (Figs. 13–15). The short tail does not bear lateral keels. In the male specimens the tail is filamentous beyond the sting (Figs. 13, A–D and 14, A–B), but in the females it is shaped like a green bean, being initially bulbous and then terminating in a fine filament (Figs. 14, C–D and 15, A–D).

Four *Himantura walga* specimens (ZMH 121965) were used for comparison (Fig. 16, A–D). These specimens were found aboard a local fishing boat in Pulau Pangkor, West Malaysia on 19th November 1984. They had been caught by the fishermen in 20–30 m depth with a trawl net.

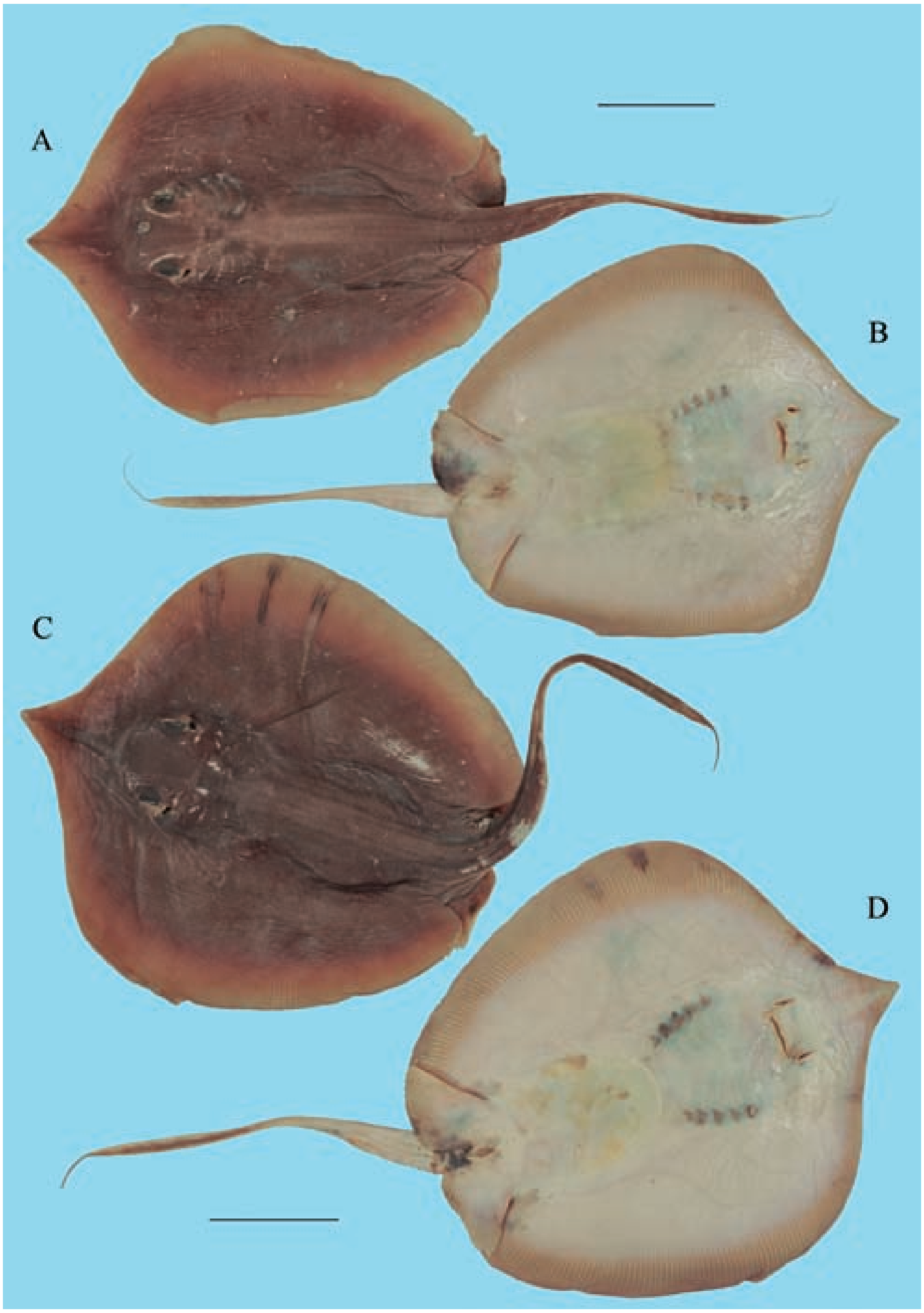
Although the highly unusual transformation of the tail in mature females of *Himantura walga* was already described by Last & Compagno (1999), it is pictured here for the first time (Figs. 14, C–D and 15, A–D). The function of the swelling is still unknown. The filamentous tails of the 79 mm and 93 mm wide juvenile females from the comparison material (ZMH 121965, Fig. 16, C–D) prove that the transformation really takes place not until the females get mature. Further evidence is supplied by the with 167 mm disc width smallest of the three adult females of ZMH 25690, in which the tail is only slightly thickened, but already shows the typically bent terminal filament (Fig. 14, C–D). As both larger females with 181 mm and 185 mm disc width have fully thickened tails (Fig. 15, A–D), females seem to get mature at disc widths of about 170 mm. This assumption corresponds with the observations by White et al. (2006) and White & Dharmadi (2007). According to these authors the males of *Himantura walga* have a similar maturity size. All three males of ZMH 25690 with disc widths of 172 mm, 174 mm and 187 mm are mature with fully developed claspers (Figs. 13, B, D and 14, B), whereas the two males of the comparison material (ZMH 121965) are still



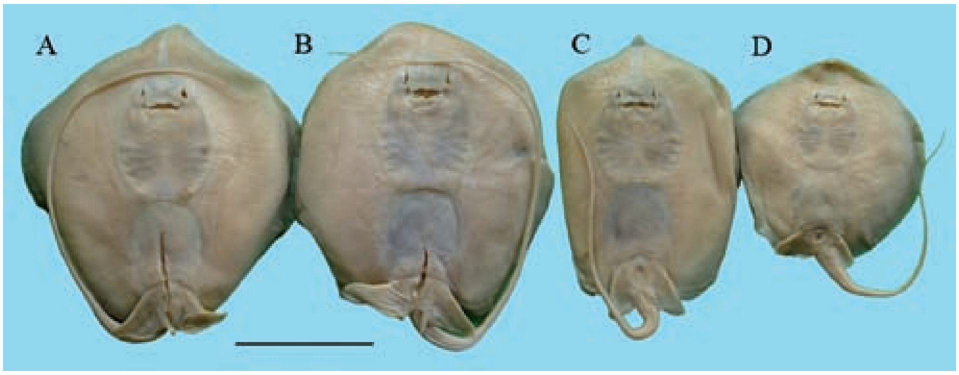
Figures 14



Figures 15



Figures 16



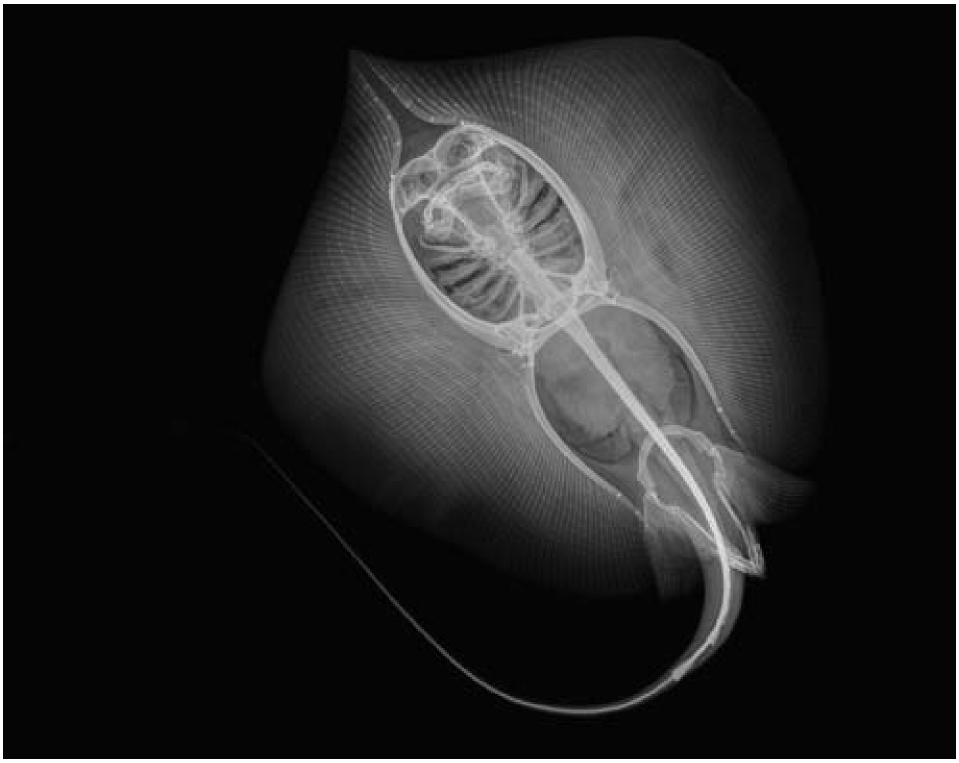
Figures 17

juvenile with not fully developed claspers at widths of 110 mm and 112 mm (Fig. 16, A–B).

Tooth row counts for the six specimens from Thailand are as follows: Male, 172 mm wide: 39 tooth rows in the upper and 43 in the lower jaw; male, 174 mm: 45 and 48 tooth rows; male, 187 mm: 40 and 46 rows; female, 167 mm: 38 and 42 rows; female, 181 mm: 40 and 44 rows; female, 185 mm: 41 and 45 rows.

The internal meristics are as follows: Male, 172 mm disc width (Fig. 17): Vertebral centra anterior to the first sting: 78, total vertebral centra count: ca. 90, monospondylous centra: 35, diplospondylous centra: ca. 55; pectoral fin rays (left/right): 101/100, ventral fin rays (left/right): 18/17 (excluding claspers). Male, 174 mm disc width: Vertebral centra anterior to the first sting: 78, total vertebral centra count: ca. 85, monospondylous centra: 36, diplospondylous centra: ca. 49; pectoral fin rays (left/right): 105/106, ventral fin rays (left/right): 17/17 (excluding claspers). Male, 187 mm disc width: Vertebral centra anterior to the first sting: 80, total vertebral centra count: ca. 90, monospondylous centra: 38, diplospondylous centra: ca. 52; pectoral fin rays (left/right): 102/104, ventral fin rays (left/right): 18/17 (excluding claspers). Female, 167 mm disc width: Vertebral centra anterior to the first sting: 77, total vertebral centra count: ca. 87, monospondylous centra: 35, diplospondylous centra: ca. 52; pectoral fin rays (left/right): 103/102, ventral fin rays (left/right): 24/24. Female, 181 mm disc width (Fig. 18): Vertebral centra anterior to the first sting: 81, total vertebral centra count: 87, monospondylous centra: 38, diplospondylous centra: 49; pectoral fin rays (left/right): 102/102, ventral fin rays (left/right): 23/23. Female, 185 mm disc width: Vertebral centra anterior to the first sting: 83, total vertebral centra count: 90, monospondylous centra: 38, diplospondylous centra: 52; pectoral fin rays (left/right): 109/108, ventral fin rays (left/right): 23/24.

Although Last & Compagno (1999) mention a maximal disc width of 18 cm for *Himantura walga*, the two larger females and the largest male of ZMH 25690 are slightly wider with 181 mm, 185 mm and 187 mm disc width. However, the maximal disc

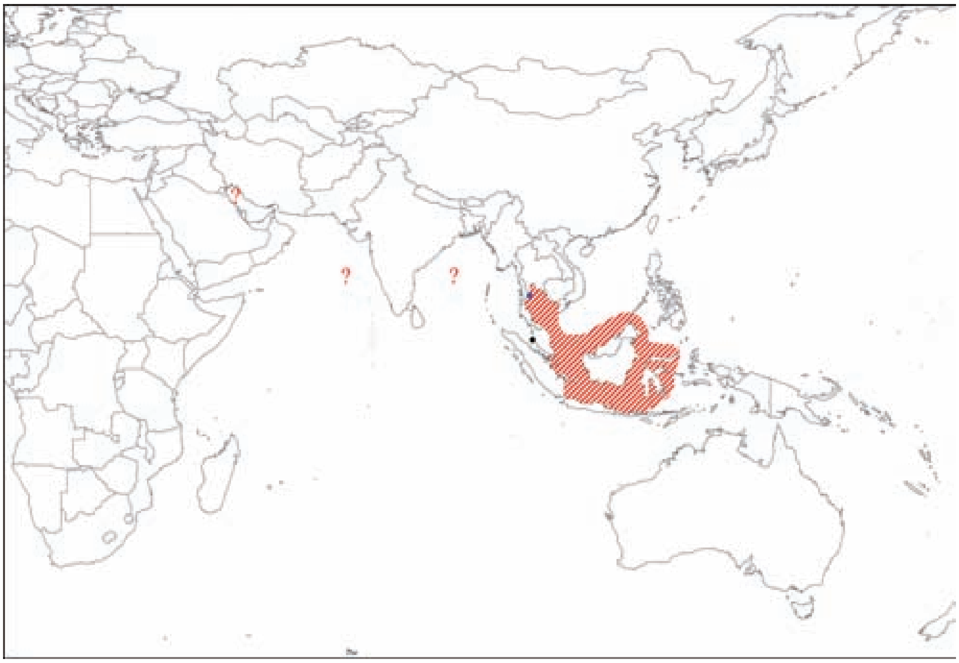


Figures 18

width of *Himantura walga* is about 24 cm following WHITE et al. (2006) and WHITE & DHARMADI (2007). According to these authors the birth size is about 8 to 11 cm disc width in *Himantura walga.* The 79 mm and the 93 mm wide females of the comparison material (ZMH 121965) represent the smallest known neonates of *Himantura walga.* These specimens indicate a smaller birth size for *Himantura walga* than previously assumed. The formerly smallest known neonate of this species was a 107 mm wide specimen reported by WHITE & DHARMADI (2007).According to LAST & COMPAGNO (1999) little is known about the biology of this mainly inshore living species, which is commercially fished in the Gulf of Thailand.

The so far known distribution of *Himantura walga* ranges from the East coast of Thailand to Southeast Indonesia. Due to confusion with *Himantura imbricata* (BLOCH & SCHNEIDER, 1801), the westward distribution of *H. walga* is still unclear (LAST & COMPAGNO 1999). The comparison material (ZMH 121965) was caught outside the so far known distribution area and represents the first confirmed record of this species in the Andaman Sea.

Two habitus photographs of each of the six specimens (ZMH 25690) are shown in Figs. 13–15 and radiographs of the 172 mm wide male and the 181 mm wide female in Figs. 17 and 18. A distribution map for *Himantura walga* is pictured in Fig. 19, in which the distribution area after LAST & COMPAGNO (1999) as well as the species dataset

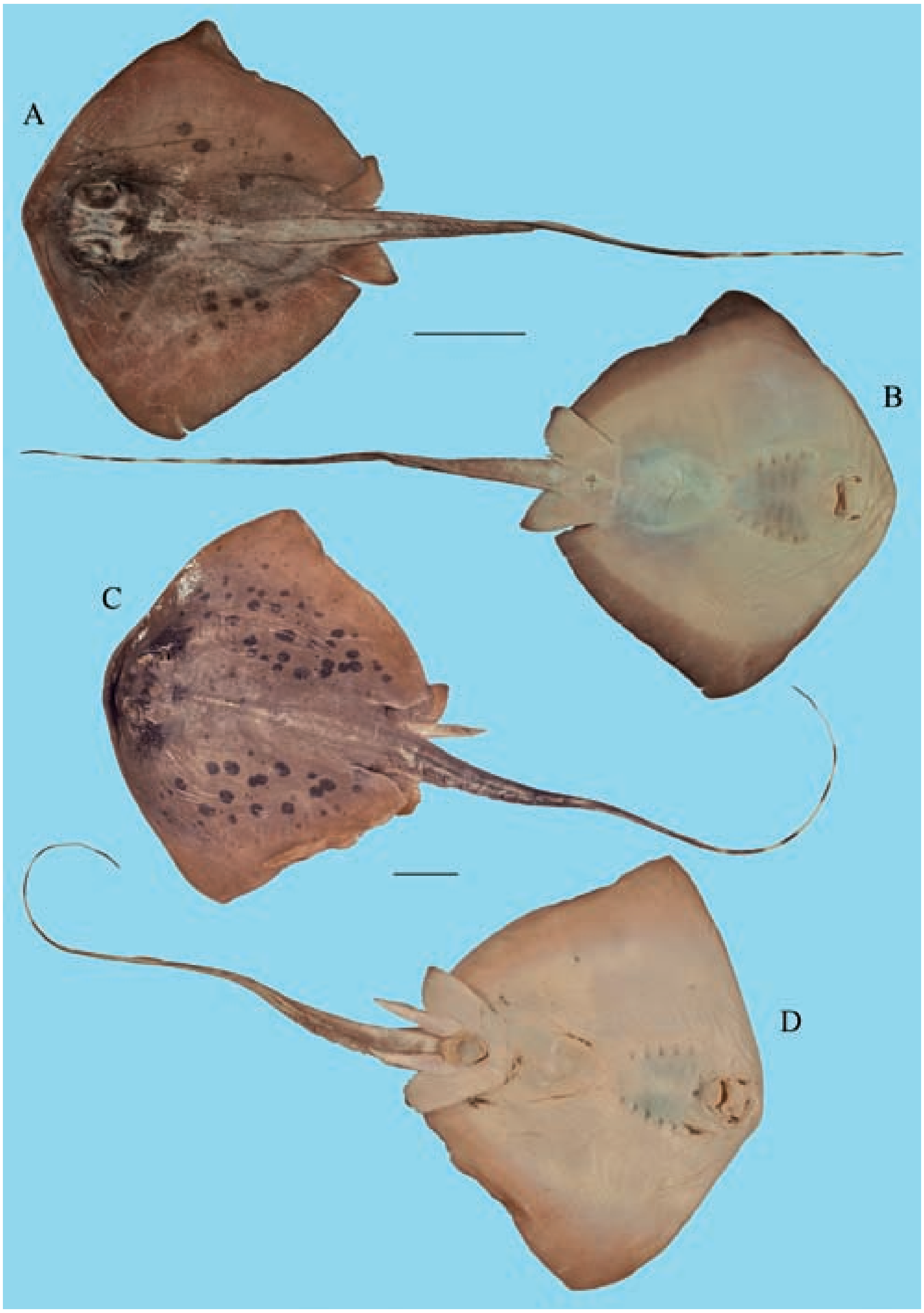


Figures 19

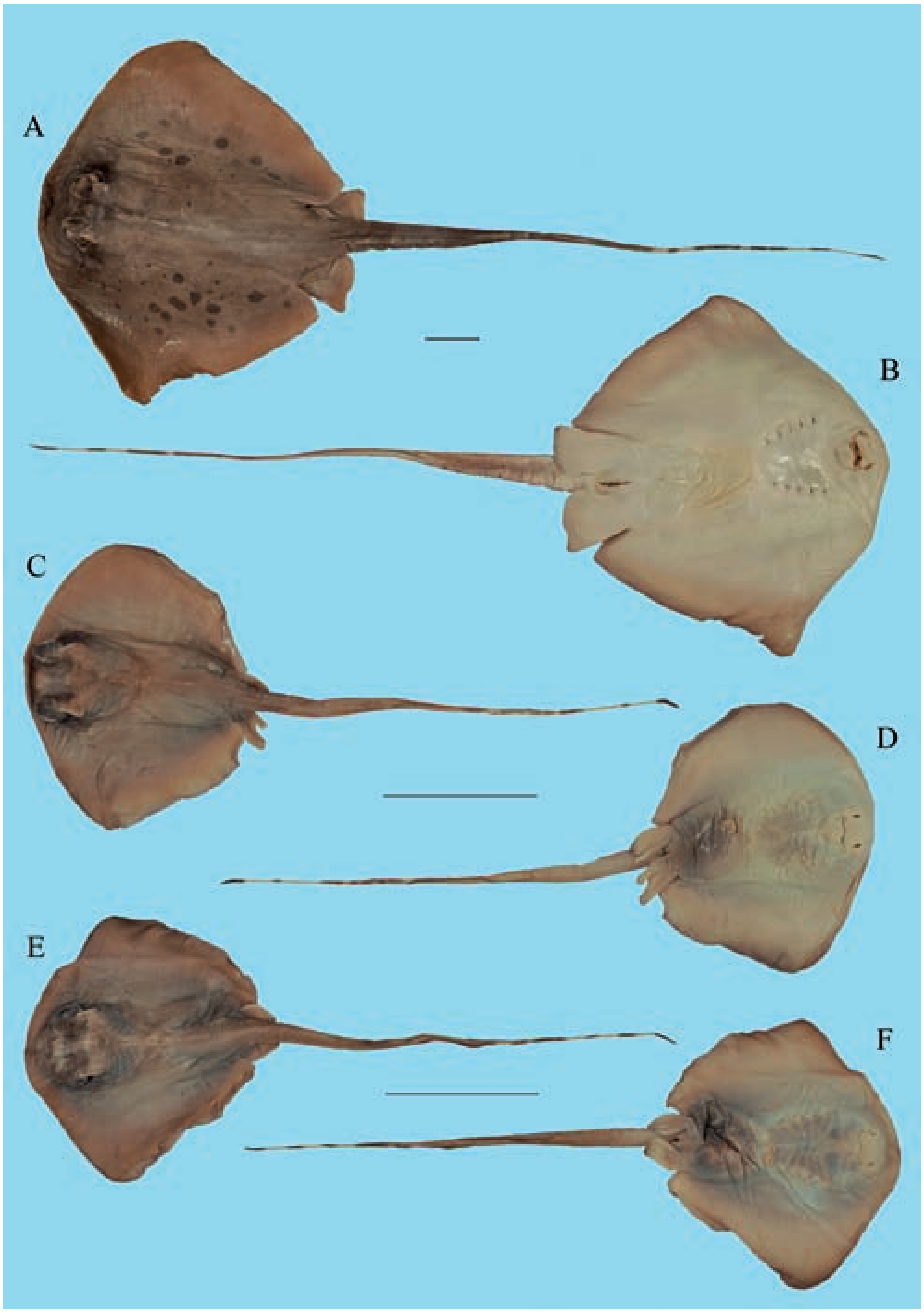
of the Global Biodiversity Information Facility (GBIF, 2010) is marked in red and white stripes, the catch location of the six Thai specimens (ZMH 25690) as a blue spot and the location of the four Malaysian individuals (ZMH 121965) as a black spot. The measurements of the Thai specimens can be found in Tables A9–A14.

Neotrygon kuhlii (Müller & Henle, 1841)

The five specimens of *Neotrygon kuhlii* (ZMH 25697–25700) were caught by local fishermen in the East Andaman Sea near Kantang on the 8th December 1993. The two embryos (ZMH 25700) were taken out of the 35.3 cm wide female ZMH 25699. As described by Last & Stevens (2009) the five specimens have – like all species of the genus *Neotrygon* – a dark band through the eyes, a short tail with alternating black and white bands on the upper half of the tail beyond the sting, a relatively small adult size and a well-developed ventral skin fold on their tail (Figs. 20–21). As specified by Last & Stevens (2009) and contrary to all other species of the genus the examined specimens – except for the two embryos – have prominent blue spots on their dorsal surface, which became discolored during the storage in alcohol (Figs. 20, A, C and 21, A). Despite this discolorization the determination by means of the spots is still unambiguous because no other species of the genus has similar spots, but instead rather complex color patterns like *Neotrygon leylandi* (Last, 1987) or small speckles like *Neotrygon picta* Last &



Figures 20



Figures 21

White, 2008b. Further characters of the five examined specimens, as described for *Neotrygon kuhlii* by Last & Stevens (2009), are a rhomboidal disc, a thickened trunk, small denticles, which are confined to a single row along the disc midline and a well-defined dorsal and ventral skin fold on the tail (Figs. 20–21).

Tooth row counts for the five examined specimens are as follows: ZMH 25697: 32 rows in the upper and 30 rows in the lower jaw, ZMH 25698: 36 and 39 rows, ZMH 25699: 29 and 32 rows, ZMH 25700: Embryo 1, 94 mm wide: 26 and about 30 rows; embryo 2, 95 mm wide: 31 and about 30 rows.

The internal meristics are as follows: ZMH 25697: Vertebral centra anterior to the first sting: 105, total vertebral centra count: ca. 145, monospondylous centra: 44, diplospondylous centra: ca. 101; pectoral fin rays (left/right): 109/109, ventral fin rays (left/right): 20/20 (excluding claspers). ZMH 25698 (Fig. 22): Vertebral centra anterior to the first sting: 103, total vertebral centra count: ca. 142, monospondylous centra: 46, diplospondylous centra: ca. 96; pectoral fin rays (left/right): 112/112, ventral fin rays (left/right): 20/20 (excluding claspers). ZMH 25699: Vertebral centra anterior to the first sting: 101, total vertebral centra count: ca. 130, monospondylous centra: 39, diplospondylous centra: ca. 91; pectoral fin rays (left/right): 109/110, ventral fin rays (left/right): 24/23. ZMH 25700: Embryo, 94 mm wide: Vertebral centra anterior to the first sting: ca. 110, total vertebral centra count: ca. 140. Embryo, 95 mm wide: Vertebral centra anterior to the first sting: ca. 110, total vertebral centra count: ca. 140.

Last & Stevens (2009) indicate a maximal disc width of at least 47 cm and a maximal total length of at least 76 cm as well as a birth size of 12–17 cm disc width and a maturing size of about 29 cm (males) or 31 cm (females) width for *Neotrygon kuhlii*. With a disc width of 9.4 cm and 9.5 cm respectively the two examined embryos were obviously not close to birth. This is further evidenced by the not yet developed bluish spots in both embryos (Fig. 21, C and E). As typical for this species, the spots are present in their mother. The small male with 18.6 cm disc width (ZMH 25697) is still juvenile with not fully developed claspers (Fig. 20, B), whereas the large male with 32.4 cm disc width is mature with well-developed claspers (Fig. 20, D).

Although *Neotrygon kuhlii* is very common and widespread (Last & Compagno 1999, Hennemann 2001, Daley et al. 2007, Last & Stevens 2009), there are still knowledge gaps regarding its biology and distribution. According to Debelius (1993) this species is always found far away from reefs, whereas it always stays nearby reefs after Patzner & Moosleitner (1999). *Neotrygon kuhlii* lives inshore to depths of 50 m (Debelius 1993, Patzner & Moosleitner 1999, Hennemann 2001) or 90 m respectively (Last & Compagno 1999, Last & Stevens 2009).

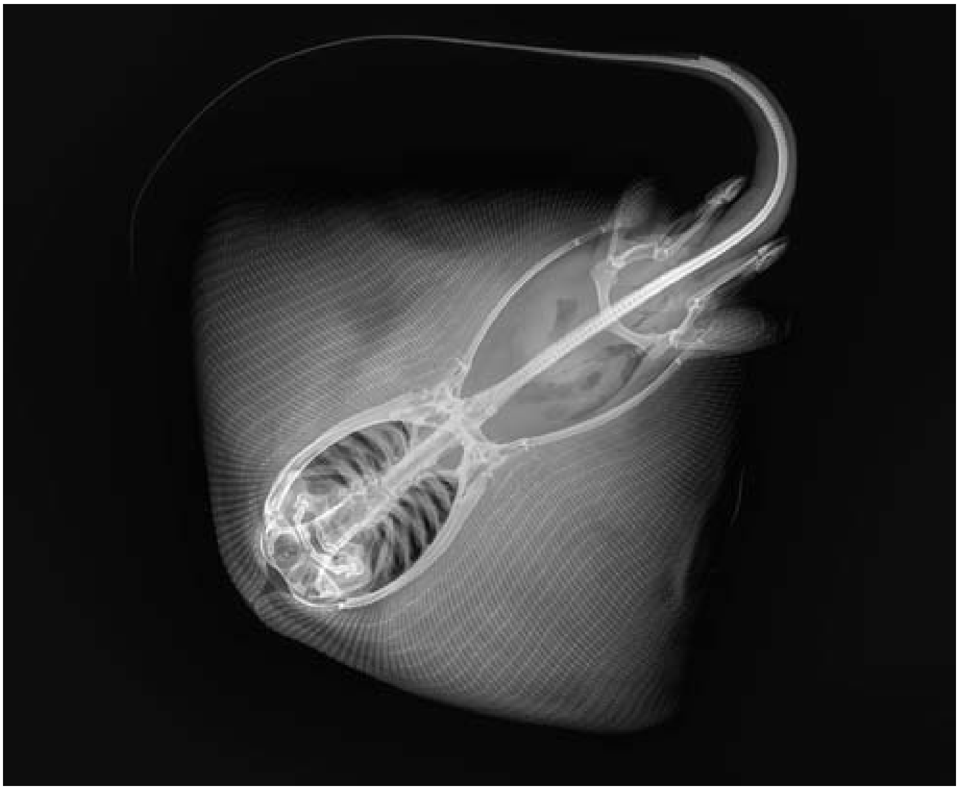
By analyzing the catch data of 625 Australian expeditions (CSIRO 2004), of which 29 voyages produced catches of *Neotrygon kuhlii* with available depth data, the known depth distribution for *Neotrygon kuhlii* could be extended considerably. The detailed data about all catches of this species in depths deeper than 90 m are shown in Table 2.

Table 2 Voyages and stations with catches of *Neotrygon kuhlii* below 90 m depth.

voyage	station	depth [m]	number of specimens
Cour 035	9	92	not specified, at least 1
SO 5/80	37	92	3
Cour 050	15	95	2
SO 5/80	19	95	1
Cour 050	5	100	2
Cour 035	24	100	not specified, at least 1
Cour 051	17	100	2
SO 5/80	38	102	1
Cour 051	32	102	11
SO 5/80	22	104	4
Cour 035	10	105	not specified, at least 1
Cour 035	21	105	not specified, at least 1
Cour 051	33	110	10
SO 4/80	51	125	not specified, at least 1
Cour 051	23	128	1
Cour 051	24	130	1
Cour 051	22	132	1
SO 7/80	39	170	1
		total:	At least 45 specimens

The considerable amount of catches below 90 m, as shown in Table 2, reveals that catches in such depths are not outliers. It can be seen thatdown to 110 m depth *Neotrygon kuhlii* was caught in quite high numbers, for example 10 specimens at station 33 (Cour 051) in 110 m depth and 11 exemplars at station 32 (also Cour 051) in 102 m depth. However, even down to 132 m depth there were quite many catches so that *Neotrygon kuhlii* seems to occur quite regularly in such depths. The specimen caught in 170 m depth represents a single value and is much deeper than all other catches. Therefore such depths are probably not typical for the species.

Despite its high abundance and wide distribution the known distribution area of *Neotrygon kuhlii* is partially fragmentary and varies between many references: According to Debelius (1993) the species is found in the whole Indian Ocean including the Red Sea. Following Burgess (1990) it occurs in the northern and western Indian Ocean, the Red Sea, the Great Barrier Reef and Southeast Asia. A similar distribution area is mentioned by Patzner & Moosleitner (1999) and Hennemann (2001), who list a distribution from Durban (South Africa) over the Red Sea and Samoa until New Caledonia and Japan in the North. Last & Compagno (1999) expand this distribution area by Melanesia and Micronesia. Following Last & Stevens (2009) *Neotrygon kuhlii* is found in the coastal waters of South Africa as well as from West India over the whole



Figures 22

northern Indian Ocean, Southeast Asia and northern Australia until Melanesia and Micronesia in the East and Japan and East China in the North. With the exception of three specimens of *Neotrygon kuhlii* that were reported from southern Africa (near Durban) by Compagno & Heemstra (1984) as well as five specimens from Zanzibar in the collection of the British Museum of Natural History, confirmed catches from the eastern coast of Africa and the Arabian coasts are still unknown. Therefore more material from these regions would be desirable. The reports from the Red Sea should also be subject to review because contrary to many other authors Last & Stevens (2009) do not include the Red Sea in the distribution area of *Neotrygon kuhlii.*

Improving the knowledge about *Neotrygon kuhlii* is complicated by the existence of different morphological variations, some of which probably not belonging to this species (Last & Compagno 1999, Last & Stevens 2009).

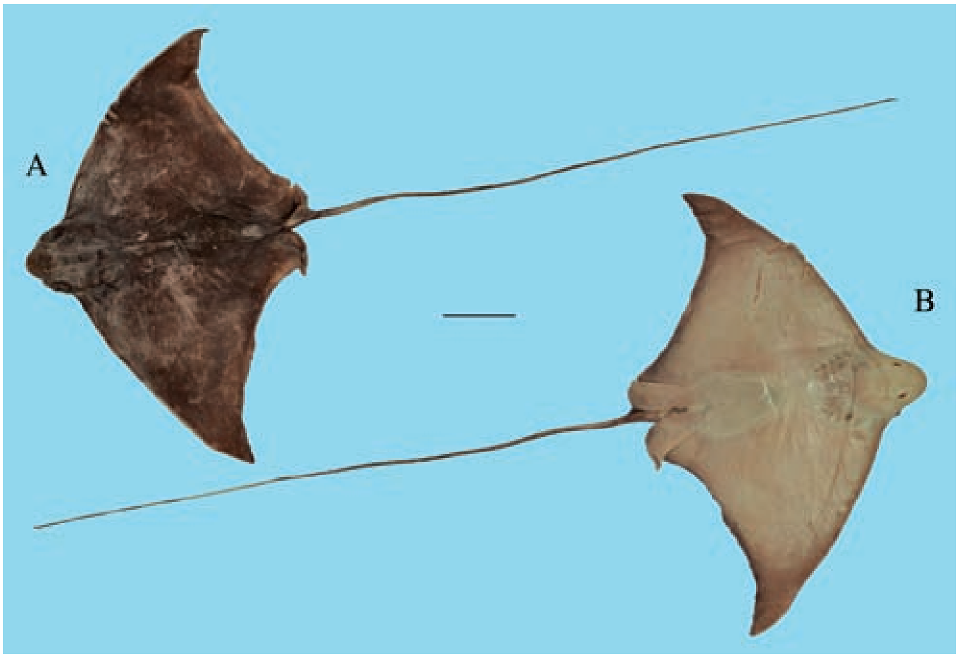
Despite the uncertainties in biology and distribution, *Neotrygon kuhlii* belongs to the most intensively commercially used ray species and is commercially fished in Thailand, too (Vidthayanon 2002, Last & Compagno 1999). However, exact data about the population status and possible negative trends in the populations of this species have not yet been collected (Fahmi & White 2007).

Two habitus photographs of each of the five specimens (ZMH 25697-ZMH 25700) are shown in Figs. 20 and 21 and a radiograph of specimen ZMH 25698 in Fig. 22. The measurements of the five specimens can be found in Tables A15–A19.

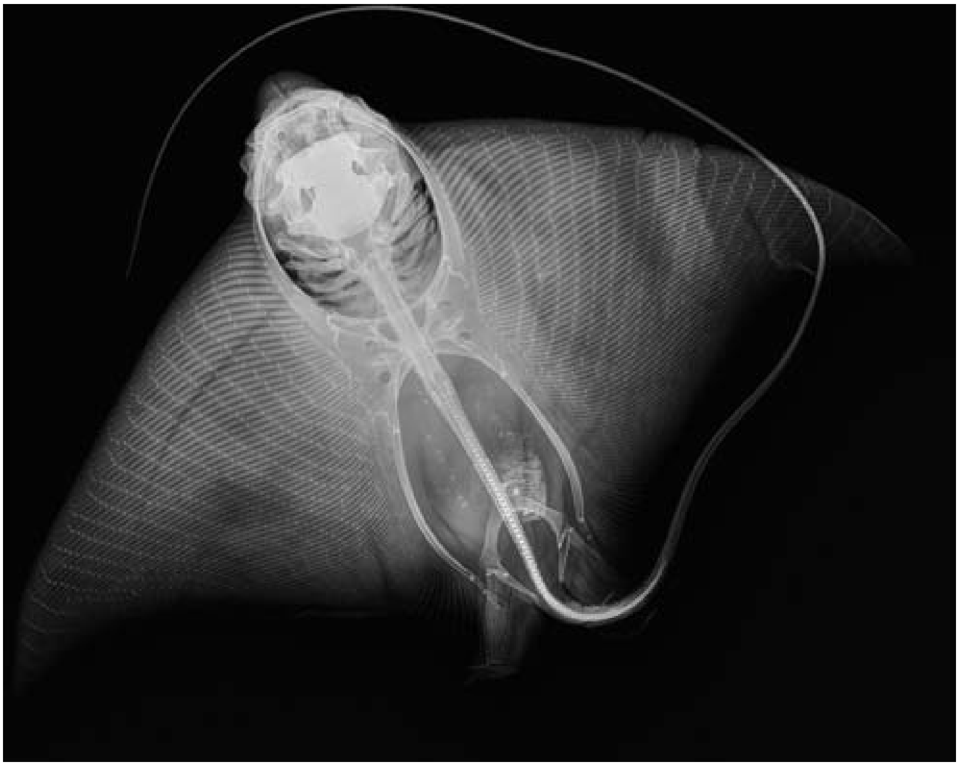
Aetomylaeus nichofii (Bloch & Schneider, 1801)

The specimen of *Aetomylaeus nichofii* (ZMH 25701) was caught by local fishermen in the East Andaman Sea near Kantang on the 8th December 1993. Like in all members of the family Myliobatidae – as described by Last & Stevens (2009) – the anterior part of the head of the examined specimen is rounded and extended beyond the disc and its eyes are located laterally on the sides of the head (Fig. 23, A–B). Furthermore it has a broad and lozenge-shaped disc and seven rows of plate-like teeth. As specified by Last & Stevens (2009) the examined specimen – like all four species of the genus *Aetomylaeus* – has no stinging spine, the single fleshy lobe around the snout is not connected to the pectoral fins, the internasal distance is shorter than the direct distance from the snout tip to the nostrils and the internasal flap is skirt-shaped (Fig. 23, A–B).

The mouth of the examined specimen is located two orbit diameters posterior to the snout tip, whereas – following Last & Stevens (2009) – it is three to four orbit diameters posterior to the snout tip in *Aetomylaeus vespertilio* (Bleeker, 1852). Contrary to *Aetomylaeus maculatus* (Gray, 1834) and *A. vespertilio* the origin of the dorsal fin is in front of the pelvic-fin insertions in the examined specimen (Fig. 23, A). In *Aetomylaeus maculatus* and *A. vespertilio* the dorsal fin originates posterior to the pelvic-fin insertions (Compagno & Last 1999a). The only other species of *Aetomylaeus* which has



Figures 23



Figures 24

the dorsal fin origin anterior or opposite the pelvic-fin insertions is *A. milvus* (Müller & Henle, 1841). However, this species has prominent ocelli on its dorsal surface, whereas the examined specimen has a plain dark brown color (Fig. 23, A) as described for adult *Aetomylaeus nichofii* specimens by Last & Stevens (2009). The juveniles of *Aetomylaeus nichofii* normally have about eight weak bands on the upper surface, but these bands probably faded during the storage in alcohol. Like *Aetomylaeus milvus* the species *A. maculatus* and *A. vespertilio* also have prominent color patterns on their upper surface.

The specimen ZMH 25701 has seven tooth rows each in the upper and lower jaw as typical for the genus.

Its internal meristics are as follows (Fig. 24): Vertebral centra anterior to the dorsal fin: 43, total vertebral centra count: 82, monospondylous centra: 36, diplospondylous centra: 46; pectoral fin rays (left/right): 89/88, ventral fin rays (left/right): 21/21.

Last & Stevens (2009) indicate a maximal disc width of at least 72 cm and a maturity size of 39–42 cm in males for *Aetomylaeus nichofii.* Therefore the examined specimen still is counted as juvenile with 31.5 cm disc width.

Although *Aetomylaeus nichofii* is widespread, it is still a little known ray species. There is a small-scale commercial fishery for this species in parts of Asia. Its distribution ranges from at least India (probably the Arabian Gulf) over whole Southeast Asia until northern Australia in the South and South Japan in the North (Last & Stevens 2009). Compagno & Last (1999a) suppose that the real distribution area is even bigger and possibly includes South and East Africa as well as the Red Sea, but this assumption needs to be verified.

Two habitus photographs of specimen ZMH 25701 are shown in Fig. 23 and a radiograph of the specimen in Fig. 24. Its measurements can be found in Table A20.

Rhinobatos formosensis Norman, 1926

The two specimens of *Rhinobatos formosensis* (ZMH 25693 and ZMH 25694) were caught between the 5th and 11th December 1993 in the coastal waters around Thailand, but unfortunately the exact location is unknown. As specified for the family Rhinobatidae by Compagno & Last (1999b) both specimens have a more or less shark-like body shape and the moderately large pectoral fins originate in front of the mouth but posterior to the snout tip and terminate posterior to the origins of the pelvic fins. Furthermore, following Last & Stevens (2009), all Rhinobatidae have a not well-developed ventral lobe of the caudal fin and the origin of the first dorsal fin is situated posterior to the pelvic fins (Fig. 27, A–D).

Like all members of the genus *Rhinobatos* the examined specimens have – as described by Compagno & Last (1999b) – no nasal curtain, diagonal nostrils (Fig. 27, B, D) and spiracles with a pair of narrow folds on their posterior margins (Fig. 27, A, C).

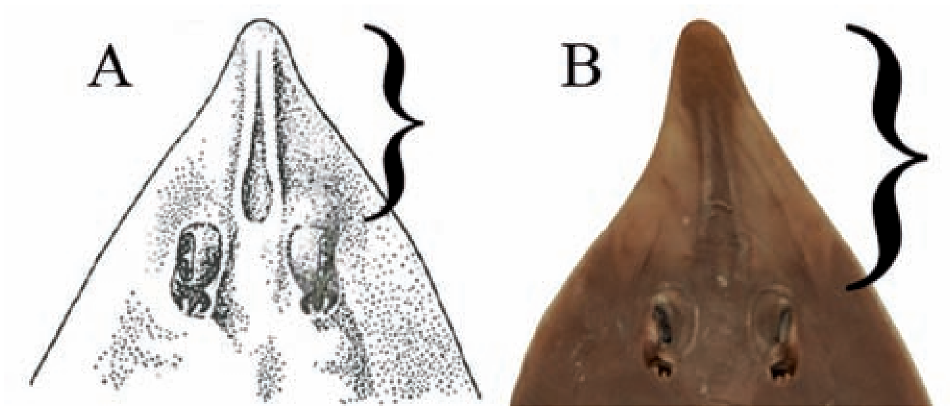
The last substantial revision of the genus *Rhinobatos* was published by Norman (1926) when several species of the genus were not yet known. After ruling out all species described after Norman's revision, two species groups of quite similar species came into question for the determination of the two examined specimens: Species group 1 with *R. holcorhynchus* Norman, 1922, *R. formosensis*, and *R. schlegelii* Müller & Henle, 1841 as well as group 2 with *R. hynnicephalus*, Richardson, 1846, *R. rhinobatus* (Linnaeus, 1758), *R. annandalei* Norman, 1926, and *R. lionotus* Norman, 1926. Important ratios for the differentiation between these groups are listed in Table 3.

Table 3 Comparison of relevant ratios in the examined specimens and the two species groups.

ratio	ZMH 25693	ZMH 25694	species group 1	species group 2
POB/ISP	2.64	2.69	2.83–3.25	2.33 – almost 3
POR/MOW	2.6	2.64	3.33–3.67	2.33–3
IDS/D1B	2.86	2.72	3.00–3.67	less than 3

with POB = praeorbital space, ISP = interspiracular distance, POR = praeoral space, MOW = mouth width, IDS = interdorsal space, D1B = base length of first dorsal fin.

Following these ratios the two examined specimens have to be assigned to species group 2. In this group the species *Rhinobatos hynnicephalus* and *R. rhinobatos* can be



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excluded because of the well-developed inner spiracular folds of the examined specimens (Fig. 27, A, C), whereas they are only small or rudimentary in *R. hynnicephalus* and *R. rhinobatos.* Contrary to *Rhinobatos annandalei,* which has a row of spines dorsomedially, both examined specimens only have a row of minute tubercles on the dorsal midline. Therefore only *Rhinobatos lionotus* comes into question, which has a well-developed inner spiracular fold and a dorsal row of minute tubercles following Norman (1926). However, the snout of this species in the drawing by Norman (1926) is strikingly shorter than in the examined specimens (Fig. 25, A–B).

The reason for this discrepancy can be found out when carefully checking the other drawings of Norman (1926). The difference is caused by deviations in the definitions of some of the measurements. These deviations produce different values for some of the measurements between the definitions of Norman (1926) and Bigelow & Schroeder (1953). The differences are contrasted for both examined specimens in Table 4.

Table 4 Important measurements for specimens ZMH 25693 and ZMH 25694 following Bigelow & Schroeder (1953) and Norman (1926).

measurement	ZMH 25693		ZMH 25694	
	value [mm] after Bigelow & Schroeder(1953)	value [mm] after Norman (1926)	value [mm] after Bigelow & Schroeder(1953)	value [mm] after Norman (1926)
POR	117	121	74	77
ISP	39	35	24	21
D1B	36	28	19.5	16.5
IDS	103	108	53	56
MOW	45	38	28	24

When calculating the ratios with the values measured after Norman (1926) the values shown in Table 5 result.

Table 5 Comparison of relevant ratios measured after Norman (1926) in the examined specimens and the two species groups.

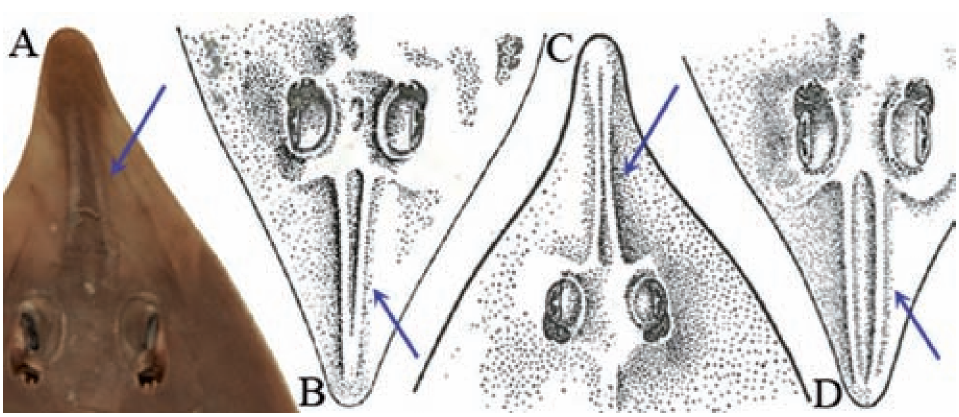
ratio	ZMH 25693	ZMH 25694	species group 1	species group 2
POB/ISP	2.94	3.07	2.83–3.25	2.33 – almost 3
POR/MOW	3.18	3.21	3.33–3.67	2.33–3
IDS/D1B	3.6	3.39	3.00–3.67	less than 3

With these readjusted values the two specimens ZMH 25693 and ZMH 25694 have to be assigned to species group 1 (with the values of the ratio praeoral snout length to mouth width lying between both groups). In species group 1 both specimens can clearly be assigned to *Rhinobatos formosensis* because the formation of their rostral ridges is equivalent to that drawn by Norman (1926) (Fig. 26, A, B). In *Rhinobatos schlegelli* the rostral ridges run too close to each other (Fig. 26, C) and in *R. holcorhynchus* they are widely separated throughout their length and run together not until close to the snout tip (Fig. 26, D).

Rhinobatos holcorhynchus can furthermore be excluded following Norman (1926) because of the ratio nostril length (NOW) to internarial distance (INW) being 1.8, whereas it is 1.33 to 1.5 in *R. formosensis* and *R. schlegelii.* In specimen ZMH 25693 the ratio NOW to INW is 1.47 and in ZMH 25694 it is 1.25. Additionally, *Rhinobatos holcorhynchus* has a row of blunt tubercles in the midline of the back, whereas the tubercles are minute in both examined specimens (Fig. 27, A, C) as specified for *R. formosensis* and *R. schlegelii* by Norman (1926).

Specimen ZMH 25693 has 103 tooth rows in the upper and 105 in the lower jaw, specimen ZMH 25694 has 79 rows in the upper and about 80 rows in the lower jaw.

The internal meristics are as follows: ZMH 25693 (Fig. 28): Synarcual with an anterior centrum-free region of 14 segments (SYS) and a posterior region with 11 embedded centra (SYC); total vertebral centra count: 190, total free vertebral centra



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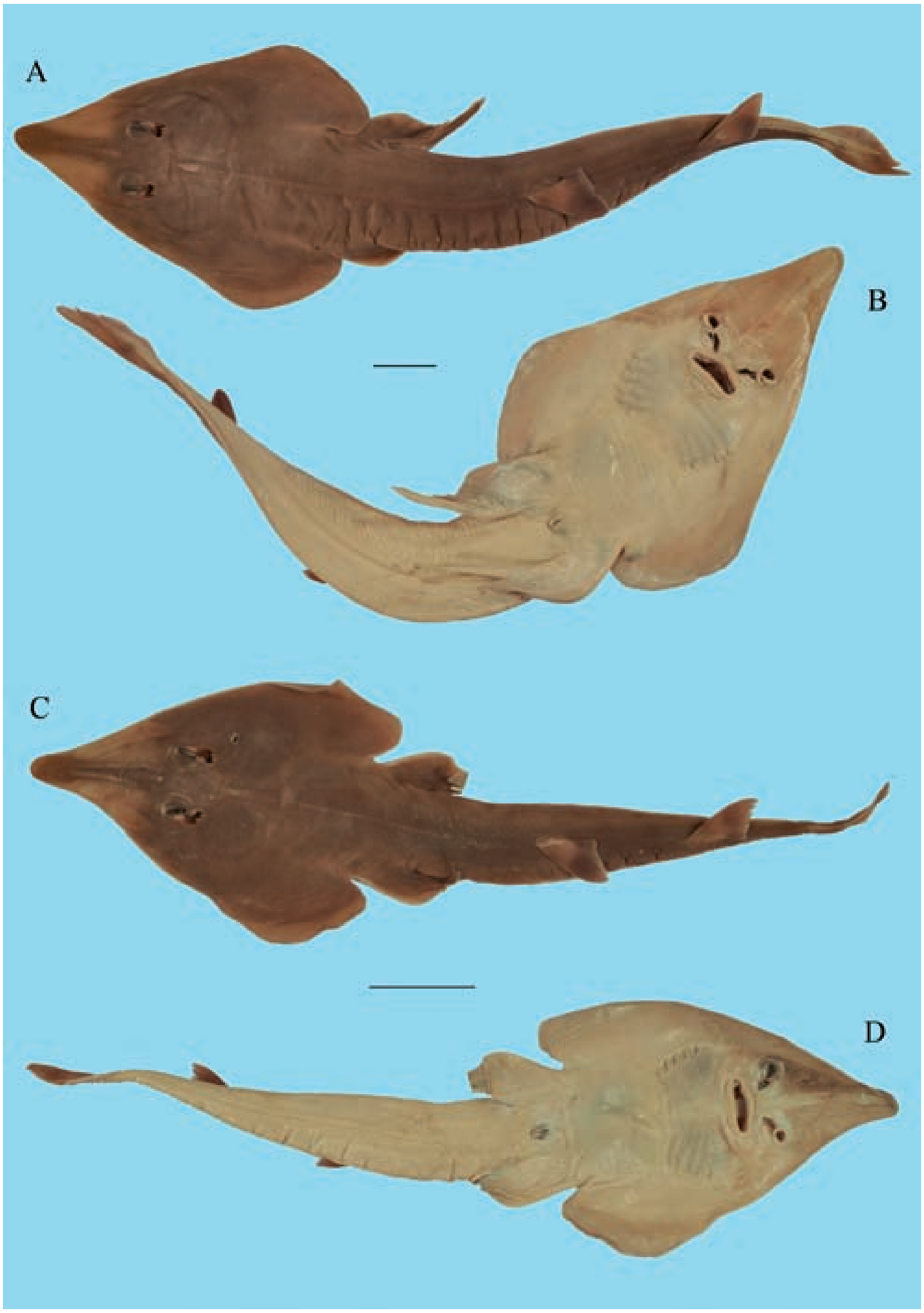
count: 179, monospondylous centra (including SYC): 37, diplospondylous centra: 153, total vertebral centra anterior to the first dorsal fin: 68, total vertebral centra anterior to the second dorsal fin: 111, total vertebral centra anterior to the caudal fin: 146, vertebral centra in the caudal fin: 44; pectoral fin rays (left/right): propterygials: 33/33, mesopterygials: 6/7, neopterygials: 1/2, metapterygials: 27/28, total basal radials: 67/70; ventral fin rays (left/right): 27/25 (excluding claspers). ZMH 25694: SYS: 13 segments, SYC: 13 centra; total vertebral centra count: 187, total free vertebral centra count: 174, monospondylous centra (including SYC): 37, diplospondylous centra: 150, total vertebral centra anterior to the first dorsal fin: 70, total vertebral centra anterior to the second dorsal fin: 110, total vertebral centra anterior to the caudal fin: 146, vertebral centra in the caudal fin: 41; pectoral fin rays (left/right): propterygials: 33/33, mesopterygials: 7/7, neopterygials: 2/2, metapterygials: 26/26, total basal radials: 68/68; ventral fin rays (left/right): 25/25 (excluding claspers).

Following Compagno & Last (1999b) *Rhinobatos formosensis* reaches a maximal total length of at least 63 cm. The adult male specimen (ZMH 25693) with fully developed claspers (Fig. 27, B) is considerably larger than this size with a total length of 73 cm. As this species gets mature not until 56 cm total length (Compagno & Last 1999b), more than 63 cm total length can surely be expected compared to the maturity and maximal length of other species of the genus. The specimen ZMH 25694 with a total length of 42 cm is clearly juvenile due to the hardly developed claspers (Fig. 27, D).

The biology and fishery exploitation of *Rhinobatos formosensis* are almost unknown (Compagno & Last 1999b). Compagno & Last (1999b) list a depth distribution from the intertidal zone to 119 m depth and a very limited distribution area because the species has been known only from Taiwan and the mouth of Manila Bay, Luzon, Philippines. Therefore it was named Taiwan Guitarfish. The two catches from Thailand represent a considerable enlargement of the distribution area and prove that this species is not endemic to the Taiwanese region. The new records are about 2500 kilometers away from the formerly known distribution area.

Two habitus photographs of each of the specimens ZMH 25693 and ZMH 25694 are shown in Fig. 27 and a radiograph of specimen ZMH 25693 in Fig. 28. A distribution map for *Rhinobatos formosensis* is pictured in Fig. 29, in which the distribution area after Last & Compagno (1999) as well as the species dataset of the Global Biodiversity Information Facility (GBIF, 2010) is marked in red and white stripes and the possible catch location of the two specimens ZMH 25693 and ZMH 25694 as blue and white stripes. The measurements of both specimens can be found in Tables A21–A22.



Figures 27

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Figures 29

Rhynchobatus australiae Whitley, 1939

The two specimens of *Rhynchobatus australiae* (ZMH 25687 and ZMH 25688) were caught by local fishermen in the Gulf of Thailand near Pak Phanang on the 7th December 1993. As members of the monotypic family Rhynchobatidae (wedgefishes) and consequently the genus *Rhynchobatus* they are – following Last & Stevens (2009) – shark-like rays with the pectoral fins and head distinct from each other as well as a caudal fin with both lobes well-developed and a deeply concave posterior margin (Figs. 30–32). Only for *Rhynchobatus djiddensis* (Forsskål, 1775) a short ventral caudal fin lobe was described and pictured by Raje et al. (2007). This abnormality was probably caused by a healed lesion because no other such specimens have been described in literature and the well-developed lower caudal fin lobe is even an important character of the whole family Rhynchobatidae. Further characteristics of this family – as described by Compagno & Last (1999c) – are a line of small thorns on dorsomedially and two short lines on the shoulders, the orbits and sometimes on the snout as well as angular and low pectoral and pelvic fins (Figs. 30–32).

Until now six species of the genus *Rhynchobatus* have been described. *Rhynchobatus laevis* (Bloch & Schneider, 1801) can be excluded in the determination of the examined specimens because in this species the origin of the first dorsal fin is situated opposite to the pelvic fins (Last & Stevens 2009), whereas in the examined specimens it is located posterior to the pelvic fins (Fig. 31, C, D). Furthermore *Rhynchobatus laevis* has a small or no black pectoral marking with only three sorrounding white spots (Last & Stevens 2009), whereas it is prominent and surrounded by four white spots in the examined specimens (Figs. 30–32). *Rhynchobatus luebberti* Ehrenbaum, 1915 can also be excluded because it has no black pectoral markings, but instead black blotches on both sides of the median dorsal row of tubercles. Additionally, this species only occurs in the tropical East Atlantic Ocean (Stehmann 1981).

The two examined specimens furthermore do not match the descriptions of *Rhynchobatus palpebratus* Compagno & Last, 2008 und *R. springeri* Last, White & Pogonoski, 2010 because they have no dark eyebrow-like markings above the eyes and also no dark spot posterior to the orbit. *Rhynchobatus palpebratus* and *R. springeri* always have eyebrow-like markings and often a dark spot posterior to the orbit (Last & Stevens 2009, Last et al. 2010). Fig. 30, which shows the two examined specimens directly after the catch, proves that the examined specimens really did not have any eyebrow-like markings, which otherwise could eventually have gotten lost during the storage in alcohol.

Furthermore, contrary to *Rhynchobatus palpebrat*us and *R. springeri*, the origin of the first dorsal fin is situated more posteriorly in the two examined specimens: In *Rhynchobatus palpebratus* the origin of the first dorsal fin is over or slightly anterior to the pelvic fin origins (Last & Compagno 2008), in *R. springeri* the origin of the first

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dorsal fin is over the origin of the pelvic fin bases (Last et al. 2010). In the examined specimens the first dorsal fin is situated posterior to the pelvic fin origins (Fig. 31, C, D) as described for *Rhynchobatus australiae* by Last & Stevens (2009) and for *R. djiddensis* by Wallace (1967).

The examined specimens (ZMH 25687 and ZMH 25688) morphologically correspond with the descriptions of the species *Rhynchobatus djiddensis* (e.g. Day 1878, Day 1889, Jordan & Fowler 1903, Garman 1913, Monkolprasit 1984 and Smith & Heemstra 2003) and *Rhynchobatus australiae* (e.g. Compagno & Last 1999c, White et al. 2006, Last & Stevens 2009, Last et al. 2010). Both species are morphologically extremely similar and are mainly differentiated by means of their distribution area: *Rhynchobatus djiddensis* occurs in the West and *R. australiae* in the East Indian Ocean (Compagno & Last 1999c). The main determination problem is that until few years ago all wedgefishes worldwide were applied to *Rhynchobatus djiddensis* (Last & Stevens 2009). That means that probably at least some of the available, above listed descriptions of *Rhynchobatus djiddensis* describe specimens of *R. australiae* or maybe even other similar, recently described species of the genus. Due to this problem the exact distribution areas of the different *Rhynchobatus* species are still unknown, too. Day (1878, 1889), Jordan & Fowler (1903), Garman (1913), Monkolprasit (1984) and Smith & Heemstra (2003) unfortunately do not mention the origin of the *Rhynchobatus djiddensis* specimens described by them. With regard to the generally fewer expeditions to the West than to the East Indian Oceans it is likely that the majority of the descriptions of *Rhynchobatus djiddensis* are based on specimens from the East Indian

Ocean and therefore on *R. australiae* or other similar species and not the real *R. djiddensis.* The only reliable source for a description of surely real *Rhynchobatus djiddensis* specimens seems to be Wallace (1967) who studied 68 specimens of both sexes, from embryos to adults, from many locations at the Southeast African Natal coast between Port Edward and Sinkwazi. Regarding the amount of dorsal tubercles there are differences between the description by Wallace (1967) and the two specimens ZMH 25687 and ZMH 25688: According to Wallace (1967) an inner series of 7–16 tubercles and an outer series of 2–3 tubercles are present above each shoulder in *Rhynchobatus djiddensis,* whereas each of the examined specimens has 6 inner and 5 outer tubercles. Additionally, there are differences in the amounts of median tubercles: Following Wallace (1967) *Rhynchobatus djiddensis* has a row of 29 to 50 tubercles anterior to the first dorsal fin and a similar row of 31 to 48 tubercles on the interdorsal space. The examined specimens each have 29 to 30 tubercles anterior to the first dorsal fin and a row of only 17 to 18 tubercles on the interdorsal space. The differences are probably not caused by the juvenility of the two specimens ZMH 25687 and ZMH 25688 because Wallace (1967) examined exemplars of all stages of growth. However, it remains unclear if the counts by Wallace (1967) are based on all 68 mentioned specimens or on few specimens only as well as how variable this character generally is in *Rhynchobatus djiddensis.* Therefore, despite the possible differences in the amounts of dorsal tubercles, certain morphological differences between *Rhynchobatus djiddensis* and *R. australiae* remain unavailable because both species generally have not been differentiated clearly until recently.

Another possible difference between *Rhynchobatus australiae* and *R. djiddensis* arise from the tooth row counts: Many references specify tooth row counts of about 40 rows per jaw for *Rhynchobatus djiddensis* (40–42 rows per jaw according to Day 1878, Day 1889, Jordan & Fowler 1903; about 40 rows per jaw following Monkolprasit 1984; 31–41 rows in the upper and 37–48 rows in the lower jaw after Wallace 1967, Smith & Heemstra 2003). These counts are far lower than the counts of the two specimens ZMH 25687 and ZMH 25688 as well as those of the other similar species of the genus, which all have more than 50 tooth rows per jaw. Specimen ZMH 25687 has 60 tooth rows in the upper and 58 in the lower jaw, ZMH 25688 has 64 rows in the upper and 62 rows in the lower jaw, *Rhynchobatus palpebratus* has about 52 tooth rows in the upper jaw (Compagno & Last 2008) and *R. springeri* has ca. 52 rows in the upper jaw, too (Last et al. 2010). The upper tooth row count of 27 listed by Fowler et al. 1941 for *Rhynchobatus yentinensis* Wang, 1933 is obviously not correct because it is extremely low compared to the other species of the genus. *Rhynchobatus yentinensis* is considered to be synonymous with *R. laevis* by Compagno & Last 2008 and Eschmeyer 2010.

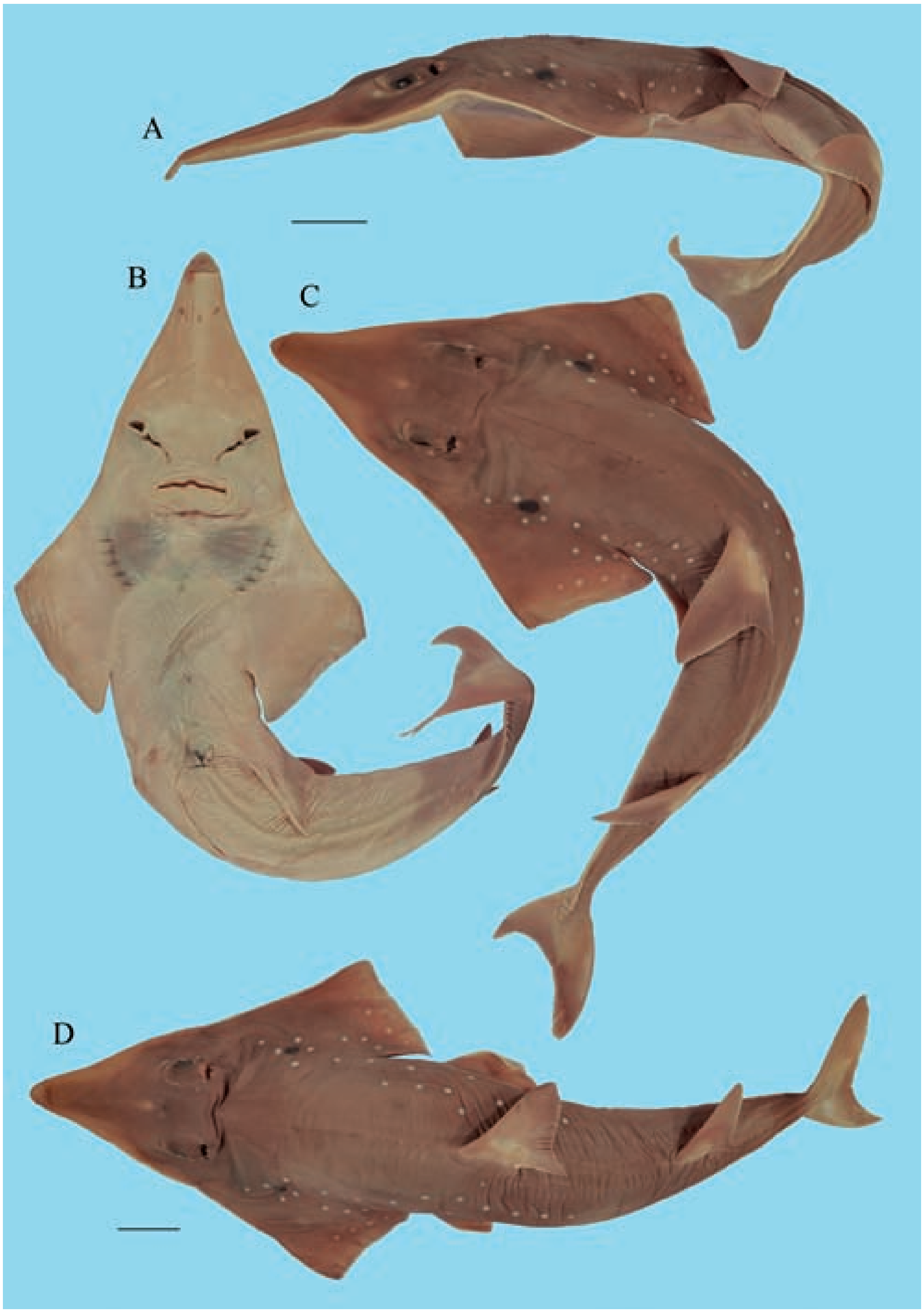
As all morphologically quite similar *Rhynchobatus* species with the exception of *R. djiddensis* have similar amounts of tooth rows in their jaws it is unlikely that *R. djid-*

densis really has much less tooth rows per jaw. The paper by Wallace (1967) indicates that the low counts for *Rhynchobatus djiddensis* are really not correct because the lower jaw of a *Rhynchobatus djiddensis* pictured on a photograph in Wallace (1967) has about 70 tooth rows, although Wallace lists round about 40 rows per jaw. The counts in Smith & Heemstra (2003) are exactly identical with those by Wallace (1967) and thus are obviously based on Wallace's numbers. The counts by Day (1878, 1889) and Jordan & Fowler (1903) are also identical among each other and therefore are probably based on the same source.

The possible reason for the low tooth row counts is a wrong method of counting the rows by not counting in a zigzag pattern but instead only counting the parallel transverse rows, which results in much lower counts than in reality. The correct method of counting the tooth rows of rays is shown in Fig. 2. The same guess is pointed out by Krefft (1961): In the remarks on *Himantura gerrardi* Krefft (1961) expresses the assumption that Fowler (1941) possibly made a mistake when counting the tooth rows of this species due to counting transverse rows instead of a zigzag pattern because Krefft (1961) got similar counts as Fowler when recounting the teeth of this species with the wrong counting method.

For *Rhynchobatus djiddensis* Krefft (1961) lists realistic tooth row counts with 57 tooth rows in the upper and 59 rows in the lower jaw. Additionally, Krefft (1961) mentions the low counts by Fowler (1941) also for this species, but does not discuss possible reasons for the difference. Krefft (1961) probably expects the same reason as which he had expressed for the low counts in *Himantura gerrardi.* Garman (1913) also gives realistic counts for *Rhynchobatus djiddensis* with 63 tooth rows for the upper jaw. Again at least some of the counts could represent counts of *Rhynchobatus australiae* or other similar species in reality due to the not known origin of the examined specimens.

The internal meristics are as follows: ZMH 25687 (Fig. 33): SYS: 19 segments, SYC: 12 centra; total vertebral centra count: 168, total free vertebral centra count: 156, monospondylous centra (including SYC): 44, diplospondylous centra: 124, total vertebral centra anterior to the first dorsal fin: 39, total vertebral centra anterior to the second dorsal fin: 89, total vertebral centra anterior to the caudal fin: 130, vertebral centra in the caudal fin: 38; pectoral fin rays (left/right): free radials before propterygium: 5/5, propterygials: 25/25, mesopterygials: 4/4, neopterygials: 4/5, metapterygials: 28/26, total basal radials: 66/65; ventral fin rays (left/right): ca. 25/ca. 25 (excluding claspers). ZMH 25688: SYS: 20 segments, SYC: 11 centra; total vertebral centra count: 175, total free vertebral centra count: 164, monospondylous centra (including SYC): 44, diplospondylous centra: 131, total vertebral centra anterior to the first dorsal fin: 40, total vertebral centra anterior to the second dorsal fin: 94, total vertebral centra anterior to the caudal fin: 133, vertebral centra in the caudal fin: 42; pectoral fin rays (left/right): free radials before propterygium: 6/7, propterygials: 26/25, mesopter-



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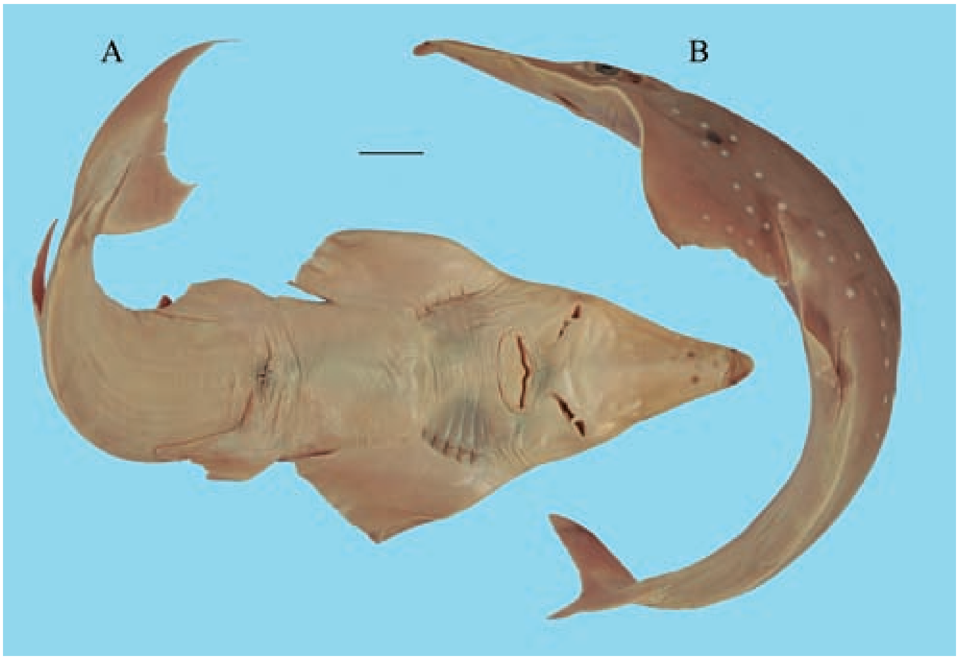

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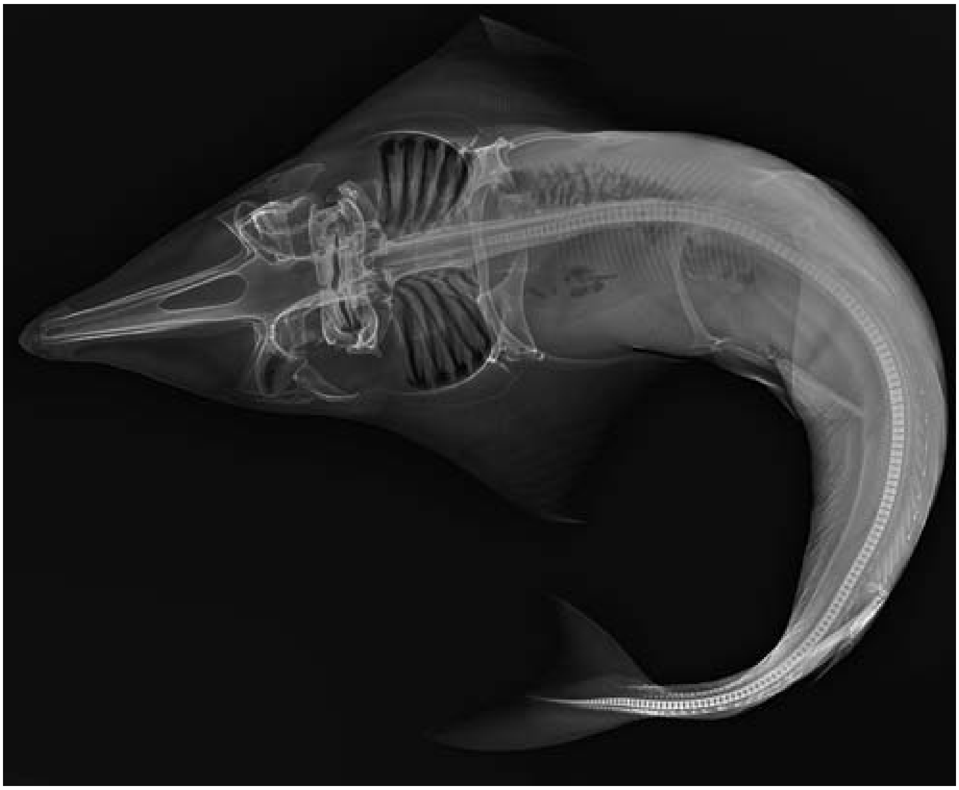
ygials: 4/4, neopterygials: 4/4, metapterygials: 26/25, total basal radials: 66/65; ventral fin rays (left/right): 27/27.

As in cases of the tooth rows, the vertebral counts for *Rhynchobatus djiddensis* are identical in Wallace (1967) and Smith & Heemstra (2003) with a precaudal vertebral count of 161–169 centra and a total count of 204–211 centra and also differ considerably from those of all other similar species of the genus, which have higher tooth row and lower vertebral counts: *Rhynchobatus laevis* has 144–149 total free vertebral centra (Last & Stevens 2009), *R. palpebratus* has 130–139 total free centra and 144–152 total centra (Compagno & Last 2008) and *R. springeri* has 113–126 total free centra and 127–139 total centra (Last et al. 2010). For *Rhynchobatus australiae* 152–153 total free vertebral centra are specified by Last & Stevens (2009) and 160–182 free centra are described by Compagno & Last (1999c). As the counts by Last & Stevens (2009) are based on less than 5 specimens these counts seem to represent untypically low counts and should be used in combination with the counts by Compagno & Last (1999c) to cover the whole level of variation. The counts by Compagno & Last (1999c) are in line with the counts of the two specimens ZMH 25687 and ZMH 25688 and corroborate the determination of these specimens as *Rhynchobatus australiae.*

Rhynchobatus australiae reaches a maximal total length of at least 187 cm according to Last & Stevens (2009) or at least 300 cm following White et al. (2006). The juveniles of this species are born at a total length of 46 to 50 cm and the length at maturity is about 130 cm in males and about 155 cm in females. Therefore both examined speci-



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mens with 69.7 cm (ZMH 25687) and 72.5 cm (ZMH 25688) total length are cleary juvenile, which is also evidenced by the hardly developed claspers of the male specimen ZMH 25687 (Fig. 31, B).

Due to the unclear taxonomic situation the exact distribution of *Rhynchobatus australiae* is unknown, but following Last & Stevens (2009) it occurs at least in the tropical and warm temperate waters around Australia and in the the whole Southeast Asian region. The distribution records from elsewhere in the Indian Ocean as well as from other parts of the West Pacific need to be verified. The clarification of the taxonomic classification is also essential for estimating the catch intensity and population trends as well as for developing effective protective actions.

Three habitus photographs of each of the specimens ZMH 25687 and ZMH 25688 are shown in Figs. 31 and 32 and a radiograph of specimen ZMH 25687 in Fig. 33. The measurements of both specimens can be found in Tables A23–A24.

Conclusion

It is important to improve our knowledge about the systematics, biology and distribution of batoids because the populations of many species are declining (Camhi et al.

1998, Stevens et al. 2000, Fowler et al. 2005). Being able to quickly and securely identify ray species is necessary to find out which species in particular are heavily used commercially or which populations are declining rapidly. A trustworthy determination is also essential for effective management and protection programs. However, the determination of many ray species is quite difficult, especially in genera with so many similar species like the genus *Rhinobatos* or, in the case of the genus *Rhynchobatus*, with several recently described new species which had been attributed to another similar species formerly. This problem is further exacerbated by the fact that detailed morphological information is not always available or sometimes misleading and out of date. Another example for the need of further research is the widespread and variable species *Neotrygon kuhlii*, which probably represents a complex of several similar species in reality (Last & Compagno 1999, Last & Stevens 2009). Additionally, the intraspecific level of variation of some characters or ratios is not always fully described like for example the variation of the ratio tail length to disc width in *Dasyatis akajei.* More knowledge deficits become apparent in the patchy distribution areas of several species like for example *Neotrygon kuhlii* and *Rhynchobatus australiae* or in the obviously not fully known distribution areas of *Himantura walga* and *Rhinobatos formosensis.*

The importance of further taxonomic and systematic research in Chondrichthyes is also visible by means of the disagreement about the exact number of known species (Fowler et al. 2005 mention 1168, Camhi et al. 2009 1115 and Last & Stevens 2009 over 1200 species), the many recently described new chondrichthyan species (e.g. Last et al. 2007, Last et al. 2008a, Last et al. 2008b, Last & Stevens 2009, Last et al. 2010) and the deficient data about population trends for almost half of all elasmobranch species (Camhi et al. 2009).

A significant contribution for improving our knowledge about the distribution and population status of many species could be provided by local fishermen. But they often only use the term “diverse Elasmobranchii” for the classification of any elasmobranch species (Bonfil 1994, Vannuccini 1999). Especially in genera with many similar species like in the genus *Rhinobatos* an exact determination will remain almost impossible and very time-consuming for non-scientists, even if more fast and easy to use identification keys like those by White et al. (2006) or Daley et al. (2007) become available.

However, the examination of collection material – eventually combined with information from local fishermen or scientists – could supply many new scientific findings and provide an important basis for the protection and management of several threatened batoid species in the future.

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Appendix

Table A1 Measurements of *Dasyatis akajei*, ZMH 25685. Weight: 1376 g, sex: Male.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	355	Distance dorsal fin to spine origin	–	Length 3rd gill opening	11
Disc length	335	Pelvic, anterior margin length	66	Length 5th gill opening	6.3
Disc length point to point	340	Pelvic, maximal length to post. tip	66	Distance between first gill slits	73
Snout tip to dorsal fin or sting origin	460	Dorsal caudal fin margin	–	Distance between fifth gill slits	48
Snout tip to pelvic tips	360	Preventral caudal fin margin	–	Head length to level fifth gill slits	167.5
Snout length, preorbital	75	Postventral caudal fin margin	–	Cloacal vent length	21.6
Snout length, preoral (to curtain edge)	84	Head width across ant. eye lens	–	Snout to anterior cloaca edge	292.4
Orbit, horizontal diameter	31	Head width at base rostral process	–	Anterior cloaca to dorsal fin origin	–
Interorbital minimal distance	43	Mouth width between lateral folds	33.4	Anterior cloaca to origin tail spine	170
Spiracle length	26	Internarial distance	33.5	Anterior cloaca to tail tip	843
Interspiracular distance (posteriorly)	65	Nostril length	13	Total length	1135.4
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	121
Dorsal fin height	–	Maximal width of nasal curtain	39.6	Clasper from posterior cloaca	101
Length tail spine	–	Length 1st gill opening	9.8	Snout angle [°]	111

Table A2 Measurements of *Dasyatis akajei*, ZMH 25686. Weight: 1047 g, sex: Male.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	323	Distance dorsal fin to spine origin	–	Length 3rd gill opening	10
Disc length	312	Pelvic, anterior margin length	68	Length 5th gill opening	6.2
Disc length point to point	318	Pelvic, maximal length to post. tip	68	Distance between first gill slits	71
Snout tip to dorsal fin or sting origin	445	Dorsal caudal fin margin	–	Distance between fifth gill slits	48
Snout tip to pelvic tips	334	Preventral caudal fin margin	–	Head length to level fifth gill slits	151.5
Snout length, preorbital	73	Postventral caudal fin margin	–	Cloacal vent length	20
Snout length, preoral (to curtain edge)	71	Head width across ant. eye lens	–	Snout to anterior cloaca edge	276
Orbit, horizontal diameter	27	Head width at base rostral process	–	Anterior cloaca to dorsal fin origin	–
Interorbital minimal distance	39	Mouth width between lateral folds	34.5	Anterior cloaca to origin tail spine	168
Spiracle length	19	Internarial distance	33	Anterior cloaca to tail tip	760
Interspiracular distance (posteriorly)	64.5	Nostril length	12	Total length	1036
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	120
Dorsal fin height	–	Maximal width of nasal curtain	40	Clasper from posterior cloaca	100
Length tail spine	–	Length 1st gill opening	9.4	Snout angle [°]	112

Table A3 Measurements of *Dasyatis zugei*, ZMH 25689. Female, 210 mm disc width. Weight: 208 g.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	210	Distance dorsal fin to spine origin	–	Length 3rd gill opening	7.5
Disc length	213	Pelvic, anterior margin length	33	Length 5th gill opening	5
Disc length point to point	217	Pelvic, maximal length to post. tip	33	Distance between first gill slits	38.5
Snout tip to dorsal fin or sting origin	259	Dorsal caudal fin margin	–	Distance between fifth gill slits	22.5
Snout tip to pelvic tips	226	Preventral caudal fin margin	–	Head length to level fifth gill slits	107
Snout length, preorbital	52	Postventral caudal fin margin	–	Cloacal vent length	10.5
Snout length, preoral (to curtain edge)	55.5	Head width across ant. eye lens	–	Snout to anterior cloaca edge	192
Orbit, horizontal diameter	18	Head width at base rostral process	–	Ant. cloaca to origin ventr. skin fold	75
Interorbital minimal distance	18.5	Mouth width between lateral folds	20.5	Anterior cloaca to origin tail spine	71
Spiracle length	7.5	Internarial distance	20.5	Anterior cloaca to tail tip	327

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Interspiracular distance (posteriorly)	29	Nostril length	7	Total length	519
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	–
Dorsal fin height	–	Maximal width of nasal curtain	21.5	Clasper from posterior cloaca	–
Length tail spine	–	Length 1st gill opening	7	Snout angle [°]	99

Table A4 Measurements of *Dasyatis zugei*, ZMH 25689. Female, 233 mm disc width. Weight: 354 g.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	233	Distance dorsal fin to spine origin	–	Length 3rd gill opening	8.5
Disc length	240	Pelvic, anterior margin length	28	Length 5th gill opening	5
Disc length point to point	244	Pelvic, maximal length to post. tip	28	Distance between first gill slits	44
Snout tip to dorsal fin or sting origin	321	Dorsal caudal fin margin	–	Distance between fifth gill slits	28
Snout tip to pelvic tips	254	Preventral caudal fin margin	–	Head length to level fifth gill slits	122
Snout length, preorbital	57	Postventral caudal fin margin	–	Cloacal vent length	14.5
Snout length, preoral (to curtain edge)	60.5	Head width across ant. eye lens	–	Snout to anterior cloaca edge	222
Orbit, horizontal diameter	20	Head width at base rostral process	–	Ant. cloaca to origin ventr. skin fold	105
Interorbital minimal distance	22	Mouth width between lateral folds	24.5	Anterior cloaca to origin tail spine	97
Spiracle length	14	Internarial distance	25	Anterior cloaca to tail tip	235
Interspiracular distance (posteriorly)	33	Nostril length	10.7	Total length	457
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	–
Dorsal fin height	–	Maximal width of nasal curtain	27	Clasper from posterior cloaca	–
Length tail spine	–	Length 1st gill opening	7.3	Snout angle [°]	97

Table A5 Measurements of *Dasyatis zugei*, ZMH 25689. Male, 164 mm disc width. Weight: 96 g.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	164	Distance dorsal fin to spine origin	–	Length 3rd gill opening	4.5
Disc length	158	Pelvic, anterior margin length	22	Length 5th gill opening	3
Disc length point to point	161	Pelvic, maximal length to post. tip	22	Distance between first gill slits	29.5
Snout tip to dorsal fin or sting origin	201	Dorsal caudal fin margin	–	Distance between fifth gill slits	20

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Snout tip to pelvic tips	165	Preventral caudal fin margin	–	Head length to level fifth gill slits	89
Snout length, preorbital	44	Postventral caudal fin margin	–	Cloacal vent length	7.5
Snout length, preoral (to curtain edge)	45.5	Head width across ant. eye lens	–	Snout to anterior cloaca edge	145
Orbit, horizontal diameter	14	Head width at base rostral process	–	Ant. cloaca to origin ventr. skin fold	58
Interorbital minimal distance	16	Mouth width between lateral folds	18	Anterior cloaca to origin tail spine	56
Spiracle length	9.5	Internarial distance	18	Anterior cloaca to tail tip	248
Interspiracular distance (posteriorly)	25	Nostril length	6	Total length	393
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	37
Dorsal fin height	–	Maximal width of nasal curtain	19	Clasper from posterior cloaca	30
Length tail spine	–	Length 1st gill opening	4.4	Snout angle [°]	93

Table A6 Measurements of *Dasyatis zugei*, ZMH 25689. Male, 178 mm disc width. Weight: 130.5 g.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	178	Distance dorsal fin to spine origin	–	Length 3rd gill opening	6.3
Disc length	177	Pelvic, anterior margin length	28	Length 5th gill opening	3
Disc length point to point	180	Pelvic, maximal length to post. tip	28	Distance between first gill slits	34
Snout tip to dorsal fin or sting origin	226	Dorsal caudal fin margin	–	Distance between fifth gill slits	22
Snout tip to pelvic tips	185	Preventral caudal fin margin	–	Head length to level fifth gill slits	98
Snout length, preorbital	53	Postventral caudal fin margin	–	Cloacal vent length	9.5
Snout length, preoral (to curtain edge)	52	Head width across ant. eye lens	–	Snout to anterior cloaca edge	163
Orbit, horizontal diameter	14.5	Head width at base rostral process	–	Ant. cloaca to origin ventr. skin fold	68
Interorbital minimal distance	18.7	Mouth width between lateral folds	20.5	Anterior cloaca to origin tail spine	61
Spiracle length	10.5	Internarial distance	21.5	Anterior cloaca to tail tip	332
Interspiracular distance (posteriorly)	26	Nostril length	7.3	Total length	495
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	45
Dorsal fin height	–	Maximal width of nasal curtain	22	Clasper from posterior cloaca	35
Length tail spine	–	Length 1st gill opening	5.7	Snout angle [°]	91

Table A7 Measurements of *Himantura gerrardi*, ZMH 25691. Weight: 247 g, sex: Male.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	220	Distance dorsal fin to spine origin	–	Length 3rd gill opening	6.2
Disc length	203	Pelvic, anterior margin length	32	Length 5th gill opening	4.5
Disc length point to point	205	Pelvic, maximal length to post. tip	32	Distance between first gill slits	41.5
Snout tip to dorsal fin or sting origin	268	Dorsal caudal fin margin	–	Distance between fifth gill slits	27
Snout tip to pelvic tips	205	Preventral caudal fin margin	–	Head length to level fifth gill slits	93.5
Snout length, preorbital	39.5	Postventral caudal fin margin	–	Cloacal vent length	13.5
Snout length, preoral (to curtain edge)	45	Head width across ant. eye lens	–	Snout to anterior cloaca edge	170
Orbit, horizontal diameter	18	Head width at base rostral process	–	Anterior cloaca to dorsal fin origin	–
Interorbital minimal distance	20.5	Mouth width between lateral folds	22	Anterior cloaca to origin tail spine	99.5
Spiracle length	15	Internarial distance	17	Anterior cloaca to tail tip	685
Interspiracular distance (posteriorly)	43.5	Nostril length	9.5	Total length	855
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	30
Dorsal fin height	–	Maximal width of nasal curtain	20.5	Clasper from posterior cloaca	20
Length tail spine	–	Length 1st gill opening	5.8	Snout angle [°]	115

Table A8 Measurements of *Himantura gerrardi*, ZMH 25692. Weight: 743 g, sex: Female.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	315	Distance dorsal fin to spine origin	–	Length 3rd gill opening	8.5
Disc length	278	Pelvic, anterior margin length	52	Length 5th gill opening	6
Disc length point to point	282	Pelvic, maximal length to post. tip	52	Distance between first gill slits	55
Snout tip to dorsal fin or sting origin	347	Dorsal caudal fin margin	–	Distance between fifth gill slits	33.5
Snout tip to pelvic tips	290	Preventral caudal fin margin	–	Head length to level fifth gill slits	127
Snout length, preorbital	55	Postventral caudal fin margin	–	Cloacal vent length	18
Snout length, preoral (to curtain edge)	60	Head width across ant. eye lens	–	Snout to anterior cloaca edge	229
Orbit, horizontal diameter	30	Head width at base rostral process	–	Anterior cloaca to dorsal fin origin	–
Interorbital minimal distance	26	Mouth width between lateral folds	27	Anterior cloaca to origin tail spine	116
Spiracle length	22	Internarial distance	23	Anterior cloaca to tail tip	931

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Interspiracular distance (posteriorly)	52	Nostril length	13	Total length	1160
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	–
Dorsal fin height	–	Maximal width of nasal curtain	28.5	Clasper from posterior cloaca	–
Length tail spine	–	Length 1st gill opening	7.5	Snout angle [°]	118

Table A9 Measurements of *Himantura walga*, ZMH 25690. Female, 167 mm disc width. Weight: 149 g.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	167	Distance dorsal fin to spine origin	–	Length 3rd gill opening	5.5
Disc length	179	Pelvic, anterior margin length	29	Length 5th gill opening	4
Disc length point to point	182	Pelvic, maximal length to post. tip	29	Distance between first gill slits	40
Snout tip to dorsal fin or sting origin	205	Dorsal caudal fin margin	–	Distance between fifth gill slits	26
Snout tip to pelvic tips	187	Preventral caudal fin margin	–	Head length to level fifth gill slits	92
Snout length, preorbital	47	Postventral caudal fin margin	–	Cloacal vent length	13.5
Snout length, preoral (to curtain edge)	49	Head width across ant. eye lens	–	Snout to anterior cloaca edge	153.5
Orbit, horizontal diameter	15	Head width at base rostral process	–	Anterior cloaca to dorsal fin origin	–
Interorbital minimal distance	16.5	Mouth width between lateral folds	19	Anterior cloaca to origin tail spine	50
Spiracle length	9.5	Internarial distance	18	Anterior cloaca to tail tip	167
Interspiracular distance (posteriorly)	30	Nostril length	8	Total length	320.5
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	–
Dorsal fin height	–	Maximal width of nasal curtain	18.3	Clasper from posterior cloaca	–
Length tail spine	–	Length 1st gill opening	5	Snout angle [°]	112

Table A10 Measurements of *Himantura walga*, ZMH 25690. Female, 181 mm disc width. Weight: 186 g.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	181	Distance dorsal fin to spine origin	–	Length 3rd gill opening	6
Disc length	193	Pelvic, anterior margin length	31.5	Length 5th gill opening	3.6
Disc length point to point	196	Pelvic, maximal length to post. tip	31.5	Distance between first gill slits	43.5
Snout tip to dorsal fin or sting origin	223	Dorsal caudal fin margin	–	Distance between fifth gill slits	30.5

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Snout tip to pelvic tips	198	Preventral caudal fin margin	–	Head length to level fifth gill slits	98.5
Snout length, preorbital	52	Postventral caudal fin margin	–	Cloacal vent length	11.5
Snout length, preoral (to curtain edge)	54	Head width across ant. eye lens	–	Snout to anterior cloaca edge	168
Orbit, horizontal diameter	16	Head width at base rostral process	–	Anterior cloaca to ant. tail swelling	100
Interorbital minimal distance	17.5	Mouth width between lateral folds	20.4	Anterior cloaca to origin tail spine	54
Spiracle length	10.7	Internarial distance	20.5	Anterior cloaca to tail tip	181
Interspiracular distance (posteriorly)	31	Nostril length	9	Total length	349
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	–
Dorsal fin height	–	Maximal width of nasal curtain	21	Clasper from posterior cloaca	–
Length tail spine	–	Length 1st gill opening	5.3	Snout angle [°]	113

Table A11 Measurements of *Himantura walga*, ZMH 25690. Female, 185 mm disc width. Weight: 204 g.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	185	Distance dorsal fin to spine origin	–	Length 3rd gill opening	5.8
Disc length	195	Pelvic, anterior margin length	33	Length 5th gill opening	3.8
Disc length point to point	198	Pelvic, maximal length to post. tip	33	Distance between first gill slits	42
Snout tip to dorsal fin or sting origin	222	Dorsal caudal fin margin	–	Distance between fifth gill slits	27.5
Snout tip to pelvic tips	200	Preventral caudal fin margin	–	Head length to level fifth gill slits	100.5
Snout length, preorbital	52	Postventral caudal fin margin	–	Cloacal vent length	10.8
Snout length, preoral (to curtain edge)	54	Head width across ant. eye lens	–	Snout to anterior cloaca edge	170
Orbit, horizontal diameter	16	Head width at base rostral process	–	Anterior cloaca to ant. tail swelling	105
Interorbital minimal distance	19	Mouth width between lateral folds	20	Anterior cloaca to origin tail spine	55
Spiracle length	9	Internarial distance	20.5	Anterior cloaca to tail tip	178
Interspiracular distance (posteriorly)	31	Nostril length	8.8	Total length	348
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	–
Dorsal fin height	–	Maximal width of nasal curtain	20.2	Clasper from posterior cloaca	–
Length tail spine	–	Length 1st gill opening	5.4	Snout angle [°]	113

Table A12 Measurements of *Himantura walga*, ZMH 25690. Male, 172 mm disc width. Weight: 169.5 g.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	172	Distance dorsal fin to spine origin	–	Length 3rd gill opening	5.6
Disc length	180	Pelvic, anterior margin length	32	Length 5th gill opening	3
Disc length point to point	184	Pelvic, maximal length to post. tip	32	Distance between first gill slits	40.5
Snout tip to dorsal fin or sting origin	213	Dorsal caudal fin margin	–	Distance between fifth gill slits	28
Snout tip to pelvic tips	189	Preventral caudal fin margin	–	Head length to level fifth gill slits	98
Snout length, preorbital	47	Postventral caudal fin margin	–	Cloacal vent length	9.5
Snout length, preoral (to curtain edge)	48	Head width across ant. eye lens	–	Snout to anterior cloaca edge	158
Orbit, horizontal diameter	15	Head width at base rostral process	–	Anterior cloaca to dorsal fin origin	–
Interorbital minimal distance	19	Mouth width between lateral folds	20.5	Anterior cloaca to origin tail spine	58
Spiracle length	10.5	Internarial distance	21	Anterior cloaca to tail tip	244
Interspiracular distance (posteriorly)	32	Nostril length	8	Total length	402
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	44.5
Dorsal fin height	–	Maximal width of nasal curtain	22	Clasper from posterior cloaca	37
Length tail spine	–	Length 1st gill opening	5.3	Snout angle [°]	111

Table A13 Measurements of *Himantura walga*, ZMH 25690. Male, 174 mm disc width. Weight: 189 g.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	174	Distance dorsal fin to spine origin	–	Length 3rd gill opening	5.8
Disc length	184	Pelvic, anterior margin length	33.5	Length 5th gill opening	4
Disc length point to point	186	Pelvic, maximal length to post. tip	33.5	Distance between first gill slits	44
Snout tip to dorsal fin or sting origin	213	Dorsal caudal fin margin	–	Distance between fifth gill slits	29
Snout tip to pelvic tips	190	Preventral caudal fin margin	–	Head length to level fifth gill slits	98
Snout length, preorbital	45.5	Postventral caudal fin margin	–	Cloacal vent length	10
Snout length, preoral (to curtain edge)	49	Head width across ant. eye lens	–	Snout to anterior cloaca edge	157
Orbit, horizontal diameter	17	Head width at base rostral process	–	Anterior cloaca to dorsal fin origin	–
Interorbital minimal distance	19.5	Mouth width between lateral folds	21	Anterior cloaca to origin tail spine	56

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Spiracle length	9	Internarial distance	23	Anterior cloaca to tail tip	194
Interspiracular distance (posteriorly)	34.5	Nostril length	7.8	Total length	351
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	42
Dorsal fin height	–	Maximal width of nasal curtain	23.5	Clasper from posterior cloaca	34
Length tail spine	–	Length 1st gill opening	5.5	Snout angle [°]	110

Table A14 Measurements of *Himantura walga*, ZMH 25690. Male, 187 mm disc width. Weight: 210 g.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	187	Distance dorsal fin to spine origin	–	Length 3rd gill opening	5.8
Disc length	193	Pelvic, anterior margin length	32.5	Length 5th gill opening	3.3
Disc length point to point	196	Pelvic, maximal length to post. tip	32.5	Distance between first gill slits	46
Snout tip to dorsal fin or sting origin	217	Dorsal caudal fin margin	–	Distance between fifth gill slits	30.5
Snout tip to pelvic tips	199	Preventral caudal fin margin	–	Head length to level fifth gill slits	103.5
Snout length, preorbital	47	Postventral caudal fin margin	–	Cloacal vent length	10.5
Snout length, preoral (to curtain edge)	50.5	Head width across ant. eye lens	–	Snout to anterior cloaca edge	165
Orbit, horizontal diameter	17.5	Head width at base rostral process	–	Anterior cloaca to dorsal fin origin	–
Interorbital minimal distance	18.5	Mouth width between lateral folds	24	Anterior cloaca to origin tail spine	55
Spiracle length	11	Internarial distance	24	Anterior cloaca to tail tip	240
Interspiracular distance (posteriorly)	35.5	Nostril length	7.5	Total length	405
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	42/46
Dorsal fin height	–	Maximal width of nasal curtain	26	Clasper from posterior cloaca	33/35
Length tail spine	–	Length 1st gill opening	5.8	Snout angle [°]	110

Table A15 Measurements of *Neotrygon kuhlii*, ZMH 25697. Weight: 139 g, sex: Male.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	186	Distance dorsal fin to spine origin	–	Length 3rd gill opening	6
Disc length	149	Pelvic, anterior margin length	36	Length 5th gill opening	4
Disc length point to point	151	Pelvic, maximal length to post. tip	36	Distance between first gill slits	32.5
Snout tip to dorsal fin or sting origin	201	Dorsal caudal fin margin	–	Distance between fifth gill slits	18

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Snout tip to pelvic tips	166	Preventral caudal fin margin	–	Head length to level fifth gill slits	69
Snout length, preorbital	24	Postventral caudal fin margin	–	Cloacal vent length	9
Snout length, preoral (to curtain edge)	26	Head width across ant. eye lens	–	Snout to anterior cloaca edge	128
Orbit, horizontal diameter	20	Head width at base rostral process	–	Anterior cloaca to dorsal fin origin	–
Interorbital minimal distance	12	Mouth width between lateral folds	18	Anterior cloaca to origin tail spine	75
Spiracle length	13	Internarial distance	14	Anterior cloaca to tail tip	260
Interspiracular distance (posteriorly)	29.3	Nostril length	6.5	Total length	388
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	27
Dorsal fin height	–	Maximal width of nasal curtain	17	Clasper from posterior cloaca	20
Length tail spine	–	Length 1st gill opening	6	Snout angle [°]	122

Table A16 Measurements of *Neotrygon kuhlii*, ZMH 25698. Weight: 892 g, sex: Male.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	324	Distance dorsal fin to spine origin	–	Length 3rd gill opening	10
Disc length	262	Pelvic, anterior margin length	61	Length 5th gill opening	6.8
Disc length point to point	267	Pelvic, maximal length to post. tip	61	Distance between first gill slits	50
Snout tip to dorsal fin or sting origin	360	Dorsal caudal fin margin	–	Distance between fifth gill slits	27.5
Snout tip to pelvic tips	280	Preventral caudal fin margin	–	Head length to level fifth gill slits	114
Snout length, preorbital	40	Postventral caudal fin margin	–	Cloacal vent length	18
Snout length, preoral (to curtain edge)	41	Head width across ant. eye lens	–	Snout to anterior cloaca edge	217
Orbit, horizontal diameter	31	Head width at base rostral process	–	Anterior cloaca to dorsal fin origin	–
Interorbital minimal distance	16	Mouth width between lateral folds	26	Anterior cloaca to origin tail spine	140
Spiracle length	20	Internarial distance	24	Anterior cloaca to tail tip	500
Interspiracular distance (posteriorly)	48	Nostril length	11	Total length	717
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	95
Dorsal fin height	–	Maximal width of nasal curtain	26	Clasper from posterior cloaca	78
Length tail spine	–	Length 1st gill opening	8	Snout angle [°]	119

Table A17 Measurements of *Neotrygon kuhlii*, ZMH 25699. Weight: 1339 g, sex: Female.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	353	Distance dorsal fin to spine origin	–	Length 3rd gill opening	12
Disc length	290	Pelvic, anterior margin length	62	Length 5th gill opening	8
Disc length point to point	298	Pelvic, maximal length to post. tip	62	Distance between first gill slits	58
Snout tip to dorsal fin or sting origin	415	Dorsal caudal fin margin	–	Distance between fifth gill slits	31
Snout tip to pelvic tips	320	Preventral caudal fin margin	–	Head length to level fifth gill slits	122
Snout length, preorbital	45	Postventral caudal fin margin	–	Cloacal vent length	30
Snout length, preoral (to curtain edge)	45	Head width across ant. eye lens	–	Snout to anterior cloaca edge	250
Orbit, horizontal diameter	37	Head width at base rostral process	–	Anterior cloaca to dorsal fin origin	–
Interorbital minimal distance	20	Mouth width between lateral folds	28	Anterior cloaca to origin tail spine	170
Spiracle length	23	Internarial distance	23.5	Anterior cloaca to tail tip	570
Interspiracular distance (posteriorly)	54	Nostril length	14	Total length	820
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	–
Dorsal fin height	–	Maximal width of nasal curtain	29	Clasper from posterior cloaca	–
Length tail spine	–	Length 1st gill opening	10	Snout angle [°]	115

Table A18 Measurements of *Neotrygon kuhlii*, ZMH 25700. Embryo, 94 mm disc width. Weight: 24.6 g, sex: Male.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	94	Distance dorsal fin to spine origin	–	Length 3rd gill opening	3.5
Disc length	75	Pelvic, anterior margin length	15	Length 5th gill opening	2
Disc length point to point	79	Pelvic, maximal length to post. tip	15	Distance between first gill slits	19
Snout tip to dorsal fin or sting origin	120	Dorsal caudal fin margin	–	Distance between fifth gill slits	10.8
Snout tip to pelvic tips	85	Preventral caudal fin margin	–	Head length to level fifth gill slits	38.5
Snout length, preorbital	10	Postventral caudal fin margin	–	Cloacal vent length	5
Snout length, preoral (to curtain edge)	14	Head width across ant. eye lens	–	Snout to anterior cloaca edge	70
Orbit, horizontal diameter	12	Head width at base rostral process	–	Anterior cloaca to dorsal fin origin	–
Interorbital minimal distance	6	Mouth width between lateral folds	10	Anterior cloaca to origin tail spine	47
Spiracle length	11.5	Internarial distance	8.5	Anterior cloaca to tail tip	150

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Interspiracular distance (posteriorly)	21	Nostril length	4	Total length	220
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	15
Dorsal fin height	–	Maximal width of nasal curtain	10	Clasper from posterior cloaca	11
Length tail spine	–	Length 1st gill opening	2.5	Snout angle [°]	114

Table A19 Measurements of *Neotrygon kuhlii*, ZMH 25700. Embryo, 95 mm disc width. Weight: 20.2 g, sex: Male.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	95	Distance dorsal fin to spine origin	–	Length 3rd gill opening	3.5
Disc length	76	Pelvic, anterior margin length	14	Length 5th gill opening	3
Disc length point to point	79	Pelvic, maximal length to post. tip	14	Distance between first gill slits	19.5
Snout tip to dorsal fin or sting origin	112	Dorsal caudal fin margin	–	Distance between fifth gill slits	10
Snout tip to pelvic tips	84	Preventral caudal fin margin	–	Head length to level fifth gill slits	38
Snout length, preorbital	10	Postventral caudal fin margin	–	Cloacal vent length	4.5
Snout length, preoral (to curtain edge)	13.7	Head width across ant. eye lens	–	Snout to anterior cloaca edge	70.5
Orbit, horizontal diameter	12	Head width at base rostral process	–	Anterior cloaca to dorsal fin origin	–
Interorbital minimal distance	6.5	Mouth width between lateral folds	10.3	Anterior cloaca to origin tail spine	43
Spiracle length	12	Internarial distance	8.8	Anterior cloaca to tail tip	140
Interspiracular distance (posteriorly)	20	Nostril length	3.6	Total length	210.5
Dorsal fin base length	–	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	13
Dorsal fin height	–	Maximal width of nasal curtain	10	Clasper from posterior cloaca	9.5
Length tail spine	–	Length 1st gill opening	3	Snout angle [°]	116

Table A20 Measurements of *Aetomylaeus nichofii*, ZMH 25701. Weight: 330 g, sex: Female.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	315	Distance dorsal fin to spine origin	–	Length 3rd gill opening	7
Disc length	189	Pelvic, anterior margin length	38	Length 5th gill opening	4
Disc length point to point	193	Pelvic, maximal length to post. tip	38	Distance between first gill slits	41
Snout tip to dorsal fin or sting origin	175	Dorsal caudal fin margin	–	Distance between fifth gill slits	23

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Snout tip to pelvic tips	200	Dorsal fin anterior margin	25	Head length to level fifth gill slits	78.5
Snout length, preorbital	16	Dorsal fin posterior margin	15	Cloacal vent length	10.5
Snout length, preoral (to curtain edge)	33	Head width across ant. eye lens	30	Snout to anterior cloaca edge	158
Orbit, horizontal diameter	22	Head width at base rostral process	52	Anterior cloaca to dorsal fin origin	18
Interorbital minimal distance	24	Mouth width between lateral folds	25	Anterior cloaca to origin tail spine	–
Spiracle length	23	Internarial distance	18	Anterior cloaca to tail tip	450
Interspiracular distance (posteriorly)	32.5	Nostril length	7	Total length	608
Dorsal fin base length	30	Anterior nostril edge to jaw angle	–	Clasper from anterior cloaca	–
Dorsal fin height	13	Maximal width of nasal curtain	27	Clasper from posterior cloaca	–
Length tail spine	–	Length 1st gill opening	6	Snout angle [°]	–

Table A21 Measurements of *Rhinobatos formosensis*, ZMH 25693. Weight: 887 g, sex: Male. Abbreviations: AAW = anterior aperture width, ANF = anterior nasal-flap base length, ANW = anterior nasal-flap base width, INA = distance between insertions of anterior nasal flaps, INM = distance between lateral margins of anterior apertures, INW = internarial distance, NOW = nostril length, PLF = posterolateral nasal-flap anterior exposed base length, PLT = posterolateral nasal-flap total length, PLW = posterolateral nasal-flap width, PNF = posterior nasal-flap base length, PNW = posterior nasal-flap width.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	219	2nd dorsal fin height	44	Total length	730
Disc length	281	Interdorsal distance	103	Clasper from anterior cloaca	123
Disc length point to point	288	Interdorsal distance (Norman 1926)	108	Clasper from posterior cloaca	114
Snout tip to origin of first dorsal fin	415	Pelvic, anterior margin length	106	Clasper outer margin length	54
Snout tip to origin of second dorsal fin	555	Pelvic, maximal length to post. tip	106	Clasper inner margin length	99
Snout tip to pelvic tips	360	Dorsal caudal fin margin	96	Mouth width between lateral folds	45
Snout length, preorbital	103	Ventral caudal fin margin	89	Mouth width after Last et al. 2004	38
Snout length, preoral to curtain edge	117	Anterior nostril edge to jaw angle	25	INW after Last et al. 2004	19
Snout length, preoral (Norman 1926)	121	Length 1st gill opening	9	INA after Last et al. 2004	16
Orbit, horizontal diameter	31	Length 3rd gill opening	11	ANW after Last et al. 2004	11

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Interorbital minimal distance	22	Length 5th gill opening	6.5	ANF after Last et al. 2004	21
Spiracle length	17.5	Distance between first gill slits	87.5	NOW after Last et al. 2004	28
Interspiracular distance (posteriorly)	39	Distance between fifth gill slits	60.5	INM after Last et al. 2004	66
Intersp. dist. (minimal; Norman 1926)	35	Head length to level fifth gill slits	187	AAW after Last et al. 2004	9.5
1st dorsal fin base length	36	Cloacal vent length	11	PLW after Last et al. 2004	4
1st dorsal fin base l. (Norman 1926)	28	Snout to anterior cloaca edge	278	PNW after Last et al. 2004	7.5
1st dorsal fin height	54	Anterior cloaca to 1st dorsal origin	135	PNF after Last et al. 2004	19
2nd dorsal fin base length	35	Anterior cloaca to 2nd dorsal origin	275	PLF after Last et al. 2004	10
2nd dorsal fin base l. (Norman 1926)	30	Anterior cloaca to tail tip	452	PLT after Last et al. 2004	17

Table A22 Measurements of *Rhinobatos formosensis*, ZMH 25694. Weight: 149 g, sex: Male. Abbreviations: See Table A21.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	134	2nd dorsal fin height	26	Total length	420
Disc length	169	Interdorsal distance	53	Clasper from anterior cloaca	47
Disc length point to point	176	Interdorsal distance (Norman 1926)	56	Clasper from posterior cloaca	40
Snout tip to origin of first dorsal fin	240	Pelvic, anterior margin length	52	Clasper outer margin length	9
Snout tip to origin of second dorsal fin	313	Pelvic, maximal length to post. tip	52	Clasper inner margin length	23
Snout tip to pelvic tips	218	Dorsal caudal fin margin	56	Mouth width between lateral folds	28
Snout length, preorbital	64.5	Ventral caudal fin margin	44	Mouth width after Last et al. 2004	24
Snout length, preoral to curtain edge	74	Anterior nostril edge to jaw angle	18	INW after Last et al. 2004	12
Snout length, preoral (Norman 1926)	77	Length 1st gill opening	6.7	INA after Last et al. 2004	9.5
Orbit, horizontal diameter	19	Length 3rd gill opening	7.1	ANW after Last et al. 2004	6
Interorbital minimal distance	13	Length 5th gill opening	5.2	ANF after Last et al. 2004	12
Spiracle length	9–10	Distance between first gill slits	53.5	NOW after Last et al. 2004	15
Interspiracular distance (posteriorly)	24	Distance between fifth gill slits	37.5	INM after Last et al. 2004	38
Intersp. dist. (minimal; Norman 1926)	21	Head length to level fifth gill slits	114	AAW after Last et al. 2004	5
1st dorsal fin base length	19.5	Cloacal vent length	10	PLW after Last et al. 2004	2.5
1st dorsal fin base l. (Norman 1926)	16.5	Snout to anterior cloaca edge	170	PNW after Last et al. 2004	3.5

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
1st dorsal fin height	29.5	Anterior cloaca to 1st dorsal origin	75	PNF after Last et al. 2004	8.5
2nd dorsal fin base length	22	Anterior cloaca to 2nd dorsal origin	145	PLF after Last et al. 2004	5.5
2nd dorsal fin base l. (Norman 1926)	19	Anterior cloaca to tail tip	250	PLT after Last et al. 2004	8

Table A23 Measurements of *Rhynchobatus australiae*, ZMH 25687. Weight: 1266 g, sex: Male. Abbreviations: See Table A21.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	240	2nd dorsal fin height	60	Total length	697
Disc length	294	Interdorsal distance	120	Clasper from anterior cloaca	85
Disc length point to point	304	Interdorsal distance (Norman 1926)	124	Clasper from posterior cloaca	65
Snout tip to origin of first dorsal fin	325	Pelvic, anterior margin length	58	Clasper outer margin length	19
Snout tip to origin of second dorsal fin	490	Pelvic, maximal length to post. tip	89	Clasper inner margin length	43
Snout tip to pelvic tips	395	Dorsal caudal fin margin	106	Mouth width between lateral folds	56
Snout length, preorbital	116	Ventral caudal fin margin	77	Mouth width after Last et al. 2004	43
Snout length, preoral to curtain edge	138	Anterior nostril edge to jaw angle	9	INW after Last et al. 2004	27
Snout length, preoral (Norman 1926)	141	Length 1st gill opening	12	INA after Last et al. 2004	42
Orbit, horizontal diameter	33.5	Length 3rd gill opening	13.2	ANW after Last et al. 2004	5
Interorbital minimal distance	35	Length 5th gill opening	9	ANF after Last et al. 2004	16
Spiracle length	9	Distance between first gill slits	95.5	NOW after Last et al. 2004	36
Interspiracular distance (posteriorly)	45	Distance between fifth gill slits	67	INM after Last et al. 2004	83
Intersp. dist. (minimal; Norman 1926)	42	Head length to level fifth gill slits	210	AAW after Last et al. 2004	10
1st dorsal fin base length	46	Cloacal vent length	23	PLW after Last et al. 2004	3
1st dorsal fin base l. (Norman 1926)	40	Snout to anterior cloaca edge	317	PNW after Last et al. 2004	2
1st dorsal fin height	77	Anterior cloaca to 1st dorsal origin	5	PNF after Last et al. 2004	10
2nd dorsal fin base length	34	Anterior cloaca to 2nd dorsal origin	170	PLF after Last et al. 2004	10
2nd dorsal fin base l. (Norman 1926)	30	Anterior cloaca to tail tip	380	PLT after Last et al. 2004	14

Table A24 Measurements of *Rhynchobatus australiae*, ZMH 25688. Weight: 1931 g, sex: Female. Abbreviations: See Table A21.

Measurement	[mm]	Measurement	[mm]	Measurement	[mm]
Disc width	265	2nd dorsal fin height	66	Total length	725
Disc length	323	Interdorsal distance	129	Clasper from anterior cloaca	–
Disc length point to point	328	Interdorsal distance (Norman 1926)	135	Clasper from posterior cloaca	–
Snout tip to origin of first dorsal fin	360	Pelvic, anterior margin length	61	Clasper outer margin length	–
Snout tip to origin of second dorsal fin	535	Pelvic, maximal length to post. tip	97	Clasper inner margin length	–
Snout tip to pelvic tips	435	Dorsal caudal fin margin	123	Mouth width between lateral folds	57.5
Snout length, preorbital	129	Ventral caudal fin margin	89	Mouth width after Last et al. 2004	49
Snout length, preoral to curtain edge	147	Anterior nostril edge to jaw angle	11.5	INW after Last et al. 2004	30
Snout length, preoral (Norman 1926)	152	Length 1st gill opening	13	INA after Last et al. 2004	48
Orbit, horizontal diameter	35.5	Length 3rd gill opening	15	ANW after Last et al. 2004	6.5
Interorbital minimal distance	40	Length 5th gill opening	10	ANF after Last et al. 2004	19
Spiracle length	9	Distance between first gill slits	103.5	NOW after Last et al. 2004	40.5
Interspiracular distance (posteriorly)	49	Distance between fifth gill slits	74.5	INM after Last et al. 2004	92
Intersp. dist. (minimal; Norman 1926)	46	Head length to level fifth gill slits	227	AAW after Last et al. 2004	11
1st dorsal fin base length	56	Cloacal vent length	20	PLW after Last et al. 2004	4
1st dorsal fin base l. (Norman 1926)	47	Snout to anterior cloaca edge	340	PNW after Last et al. 2004	1.5
1st dorsal fin height	84	Anterior cloaca to 1st dorsal origin	5	PNF after Last et al. 2004	12
2nd dorsal fin base length	39	Anterior cloaca to 2nd dorsal origin	180	PLF after Last et al. 2004	11
2nd dorsal fin base l. (Norman 1926)	33	Anterior cloaca to tail tip	385	PLT after Last et al. 2004	16

References

Adobe (1990–2008): Photoshop CS4 Version 11.0.1. Adobe Systems, Inc. San Jose, California, USA.

Amante, C. & Eakins, B.W. (2009): ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. NOAA Technical Memorandum NESDIS NGDC-24, 19.

Bigelow, H.B. & Schroeder, W.C. (1953): Sawfishes, guitarfishes, skates and rays, and chimaeroids. In: Fishes of the western North Atlantic, Bigelow, H.B. & Schroeder, W.C. (eds.). Mem. Sears. Found. Mar. Res. 1(2), Yale University, New Haven.

Bonfil, R. (1994): Overview of world elasmobranch fisheries. FAO Fish. Tech. Pap. 341. FAO, Rome.

Burgess, W. (1990): Atlas der Meerwasser Aquarium Fische. Bede, Kollnburg.

Camhi, M., Fowler, S.L., Musick, J.A., Bräutigam, A. & Fordham, S.V. (1998): Sharks and their Relatives – Ecology and Conservation. Occ. Pap. IUCN Species Surv. Comm. 20. IUCN, Gland, Switzerland & Cambridge, UK.

Camhi, M.D., Valenti, S.V., Fordham, S.V., Fowler, S.L. & Gibson, C. (2009): The Conservation Status of Pelagic Sharks and Rays: Report of the IUCN Shark Specialist Group Pelagic Shark Red List Workshop. IUCN Species Surv. Comm. Shark Spec. Group. Newbury, UK.

Compagno, L.J.V. & Last, P.R. (1999a): Myliobatidae. Eagle rays. In: FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volume 3. Batoid Fishes, Chimaeras and Bony Fishes Part 1 (Elopidae to Linophrynidae), Carpenter, K.E. & Niem, V.H. (eds.). FAO, Rome.

Compagno, L.J.V. & Last, P.R. (1999b): Rhinobatidae. In: FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volume 3. Batoid Fishes, Chimaeras and Bony Fishes Part 1 (Elopidae to Linophrynidae), Carpenter, K.E. & Niem, V.H. (eds.). FAO, Rome.

Compagno, L.J.V. & Last, P.R. (1999c): Rhinidae (=Rhynchobatidae). Wedgefishes. In: FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volume 3. Batoid Fishes, Chimaeras and Bony Fishes Part 1 (Elopidae to Linophrynidae), Carpenter, K.E. & Niem, V.H. (eds.). FAO, Rome.

Compagno, L.J.V. & Last, P.R. (2008) A new species of wedgefish, *Rhynchobatus palpebratus* sp. nov. (Rhynchobatoidei: Rhynchobatidae), from the Indo-West Pacific. In: Descriptions of New Australian Chondrichthyans, Last, P.R., White, W.T. & Pogonoski, J.J. (eds.). CSIRO Marine and Atmospheric Research Paper 022. CSIRO, Hobart, Australia.

CSIRO (2004): CSIRO Marine Data Trawler. URL: http://www.marine.csiro.au/warehouse/jsp/loginpage.jsp, accessed 12 April 2010.

Daley, R.K., Stevens, J.D., Last, P.R. & Yearsley, G.K. (2007): Field Guide to Australian Sharks & Rays. Reprint with minor correction. CSIRO, Hobart, Australia.

Day, F. (1878): The Fishes of India Day; Being a Natural History of the Fishes Known to Inhabit the Seas and Fresh Waters of India, Burma, and Ceylon – Vol. 1. Bernard Quaritsch, London.

Day, F. (1889): The Fauna of British India including Ceylon and Burma. Fishes – Vol. 1. Taylor & Francis, London.

Debelius, H. (1993): Fischführer Indischer Ozean. Tetra, Melle.

Ebert, D.A. & Winton, M.V. (2010): Chondrichthyans of High Latitude Seas. In: Sharks and their Relatives II: Biodiversity, Adaptive Physiology, and Conservation, Carrier, J.C., Musick, J.A. & Heithaus, M.R. (eds.). CRC Press, Boca Raton, Florida.

Eschmeyer, W.N. (2010) (ed.): Catalog of Fishes electronic version (25 October 2010). URL: http://research.calacademy.org/ichthyology/catalog/fishcatmain.asp.

ESRI (1992–2007): ArcExplorer-Java Edition for Education Version 2.3.2. Environmental Systems Research Institute, Inc., Redlands, CA.

ESRI (1999–2009): ArcMap Version 9.3.1. Environmental Systems Research Institute, Inc., Redlands, CA.

Fahmi & White, W. (2007): *Dasyatis kuhlii*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.2. URL: http://www.iucnredlist.org, accessed 16 August 2010.

Fowler, H.W. (1941): Contributions to the Biology of the Philippine Archipelago and Adjacent Regions. The Fishes of the Groups Elasmobranchii, Holocephali, Isospondyli and Ostariophysi obtained by the United States Bureau of Fisheries Steamer "Albatross" in 1907 to 1910, Chiefly in the Philippine Islands and Adjacent Seas. Bull. U.S. Nat. Mus. 100(13).

Fowler, S.L., Cavanagh, R.D., Camhi, M., Burgess, G.H., Cailliet, G.M., Fordham, S.V., Simpfendorfer, C.A. & Musick, J.A. (2005): Sharks, Rays and Chimaeras: The status of the Chondrichthyan Fishes. Status Survey. IUCN Species Surv. Comm. Shark Spec. Group. IUCN, Gland, Switzerland & Cambridge, UK.

Garman, S. (1913): The Plagiostomia (Sharks, Skates, and Rays). Mem. Mus. Comp. Zool., Harv. Coll. XXXVI. Cambridge, Mass., USA.

GBIF (2010): Global Biodiversity Information Facility. URL: http://data.gbif.org/welcome.htm, accessed 06 August 2010.

Hennemann, R.M. (2001): Haie & Rochen weltweit. Jahr, Hamburg.

Jordan, D.S. & Fowler, H.W. (1903): A Review of the Elasmobranchiate Fishes of Japan. Proc. U.S. Nat. Mus. 26(1324): 593–674.

Krefft, G. (1961): Knorpelfische (Chondrichthyes), gesammelt von der Deutschen Indien-Expedition 1955/58. Mitt. Hamburg. Zool. Mus. Inst. 59: 141–178.

Krefft, G. (1968): Knorpelfische (Chondrichthyes) aus dem tropischen Ostatlantik. Atlantide Rep. 10: 33–76.

Last, P.R. & Compagno, L.J.V. (1999): Dasyatidae. In: FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volume 3. Batoid Fishes, Chimaeras and Bony Fishes Part 1 (Elopidae to Linophrynidae). Carpenter, K.E. & Niem, V.H. (eds.). FAO, Rome.

Last, P.R., Compagno, L.J.V. & Nakaja, K. (2004): *Rhinobatos nudidorsalis*, a new species of shovelnose ray (Batoidea: Rhinobatidae) from the Mascarene Ridge, central Indian Ocean. Ichthyol. Res. 51: 153–158.

Last, P.R. & Stevens, J.D. (2009): Sharks and Rays of Australia. CSIRO, Hobart, Australia.

Last, P.R. & White, W.T. (2008a): *Dasyatis parvonigra* sp. nov., a new species of stingray (Myliobatoidei: Dasyatidae) from the tropical eastern Indian Ocean. In: Descriptions of New Australian Chondrichthyans, Last, P.R., White, W.T. & Pogonoski, J.J. (eds.). CSIRO Mar. Atmos. Res. Pap. 022. CSIRO, Hobart, Australia.

Last, P.R. & White, W.T. (2008b): Resurrection of the genus *Neotrygon* Castelnau (Myliobatoidei: Dasyatidae) with the description of *Neotrygon picta* sp. nov., a new species from northern Australia. In: Descriptions of New Australian Chondrichthyans, Last, P.R., White, W.T. & Pogonoski, J.J. (eds.). CSIRO Mar. Atmos. Res. Pap. 022. CSIRO, Hobart, Australia.

Last, P.R., White, W.T. & Pogonoski, J.J. (2007) (eds.): Descriptions of New Dogfishes of the Genus *Squalus* (Squaloidea: Squalidae). CSIRO Mar. Atmos. Res. Pap. 014. CSIRO, Hobart, Australia.

Last, P.R., White, W.T., Pogonoski, J.J. & Gledhill, D.C. (2008a) (eds.): Descriptions of New Australian Skates (Batoidea: Rajoidei). CSIRO Mar. Atmos. Res. Pap. 021. CSIRO, Hobart, Australia.

Last, P.R., White, W.T. & Pogonoski, J.J. (2008b) (eds.): Descriptions of new AustralianChondrichthyans. CSIRO Mar. Atmos. Res. Pap. 022. CSIRO, Hobart, Australia.

Last, P.R., White, W.T. & Pogonoski, J.J. (2010) (eds.): Descriptions of New Sharks and Rays from Borneo. CSIRO Mar. Atmos. Res. Pap. 032. CSIRO, Hobart, Australia.

Monkolprasit, S. (1984): The cartilaginous fishes (class Elasmobranchii) found in Thai waters and adjacent areas. Kasetsart University, Thailand.

Müller, J. & Henle, F.G.J. (1838–41): Systematische Beschreibung der Plagiostomen. Veit & Comp., Berlin (1–28 published in 1838, reset 27–28, 29–102 in 1839, i-xxii + 103–200 in 1841).

Myers, R., & Worm, B. (2003): Rapid worldwide depletion of predatory fish communities. Nature 423: 280–283.

Norman, J.R. (1926): A synopsis of the rays of the family Rhinobatidae, with a revision of the genus *Rhinobatus.* Proc. Zool. Soc. Lond. 1926(4): 941–982.

Patzner, R.A. & Moosleitner, H. (1999): Mergus Meerwasser-Atlas Band 6, Non-Perciformes (Nicht-Barschartige). Mergus, Melle.

Raje, S.G., Sivakami, S., Mohan Raj, G., Manoj Kumar, P.P., Raju, A. & Joshi, K.K. (2007): An atlas on the elasmobranch fishery resources of India. CMFRI Spec. Pub. 95. CMFRI, Cochin, India.

Serena, F. (2005): Field identification guide to the sharks and rays of the Mediterranean and Black Sea. FAO Species Identification Guide for Fishery Purposes. FAO, Rome.

Smith, M.M. & Heemstra, P.C. (2003) (eds.): Smiths' sea fishes. Struik publishers, Cape Town, South Africa.

Stehmann, M. (1981): Rhynchobatidae. In: FAO species identification sheets for fishery purposes. Eastern Central Atlantic (fishing areas 34, 47 (in part)), Vol. 5, Fischer, W., Bianchi, G. & Scott, W.B. (eds.). FAO, Rome.

Stevens, J.D., Bonfil, R., Dulvy, N.K., & Walker, P.A. (2000): The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. ICES Jour. Mar. Sci. 57: 476–494.

Vannuccini, S. (1999): Shark utilization, marketing and trade. FAO Fish. Tech. Pap. 389. FAO, Rome.

Vidthayanon, C. (2002): Elasmobranch Diversity and Status in Thailand. In: Elasmobranch Biodiversity, Conservation and Management – Proceedings of the International Seminar and Workshop Sabah, Malaysia, July 1997, Fowler, S.L., Reed, T.M. & Dipper, F.A. (eds.). Occ. Pap. IUCN Species Surv. Comm. 20. IUCN, Gland, Switzerland & Cambridge, UK.

Wallace, J.H. (1967): The batoid fishes of the east coast of southern Africa. Part I: Sawfishes and guitarfishes. S. African Ass. Mar. Biol. Res., Oceanogr. Res. Inst., Invest. Rep. 15: 1–32.

White, W.T. & Dharmadi (2007): *Species and size compositions and reproductive biology of rays (Chondrichthyes, Batoidea) caught in target and non-target fisheries in eastern Indonesia.* Journal of Fish Biology 70: 1809–1837.

White, W.T., Last, P.R., Stevens, J.D., Yearsley, G.K., Fahmi & Dharmadi (2006): Economically important sharks and rays of Indonesia. ACIAR, Canberra, Australia.