The Maugean Skate, *Zearaja maugeana* sp. nov. (Rajiformes: Rajidae) — a micro-endemic, Gondwanan relict from Tasmanian estuaries

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Abstract

A new species of rajin skate, *Zearaja maugeana* sp. nov., is described on the basis of specimens from two estuaries in remote southwestern Tasmania. The species, known locally as the Maugean Skate, has been assessed as Endangered in the *IUCN Red List of Threatened Animals* based on its rarity and very narrow geographic range. It is also one of the few skates worldwide to occur mainly in brackish water. The Maugean Skate belongs to a group of anatomically conservative, *Dipturus*-like skates conforming to the currently unrecognized genus *Zearaja* Whitley. This ancient group, with a Gondwanan lineage possibly dating back to the Cretaceous, contains at least two other species: *Z. nasuta* from New Zealand and *Z. chilensis* from South America. The skeletal morphologies of the *Zearaja* species are compared with typical *Dipturus* skates and their phylogenetic position discussed.

Key words: Rajidae, skate, new species, estuarine, Tasmania, *Zearaja*

Introduction

In 1979, a series of exploratory trawl surveys were initiated to investigate commercial fish resources on the continental shelf and slope off southeastern Australia. Some skates (family Rajidae) caught were unidentifiable and this initiated a local revision of the fauna by the senior author. The most problematic subgroups were those members of the genus *Dipturus* (then assigned to *Raja*) which contained new taxa from both inshore and deep continental slope habitats. By the mid 1980's, this fauna had been well delineated with four rajin skates, *Dipturus cerva* (Whitley 1939), *D. lemprieri* (Richardson 1845), *D. whitleyi* (Iredale 1938), and an undescribed species, *D.* sp. A (*sensu* Last & Stevens 1994), known from the continental shelf. Of these, *D. whitleyi*, a large skate that reaches more than 1 m disc width, and the smaller and more common *D. lemprieri*, were known to occur frequently in coastal marine habitats of Tasmania. However, no skates were recorded from the brackish middle and upper estuaries of the region.

Tasmania's coast is geomorphologically and hydrologically complex and displays a rich array of marine habitats within a comparatively small geographic area. Perhaps the most unusual of these environments is the biologically complex region known as Port Davey (Figure 1), a ria estuary (i.e. derived from a drowned river valley) that is now a marine national park (Tasmania Parks & Wildlife Service 2006). This remote estuary, which is embedded in the 1.4 million ha Tasmanian Wilderness World Heritage Area in southwestern Tasmania, encompasses about 20% of the Tasmanian landmass. It includes a large coastal inlet that extends inland as a 12 km long channel (Bathurst Channel) leading to a 40 km^2 estuarine basin (Bathurst Harbour). The biota of the channel, about 50 m deep and permanently stratified, is unlike that found anywhere else around Australia, sharing superficial affinities with the fiords of Patagonia and southern New Zealand (Edgar et al. *in press*) High tannin loadings released from runoff over button-grass plains eliminate light in shallow depths. Consequently, coastal algal communities found typically elsewhere in the region are replaced by rich and unusual invertebrate communities, elements of which are related to animals usually found deeper offshore on the adja-

cent continental slope. Bathurst Harbour is uniformly shallow (10 m or less), very silty, and its waters are fully mixed, strongly tannic, and oligo-mesohaline (salinity usually less than 10 ppt). Its epibenthos is relatively depauperate but until recently, remained largely undiscovered.
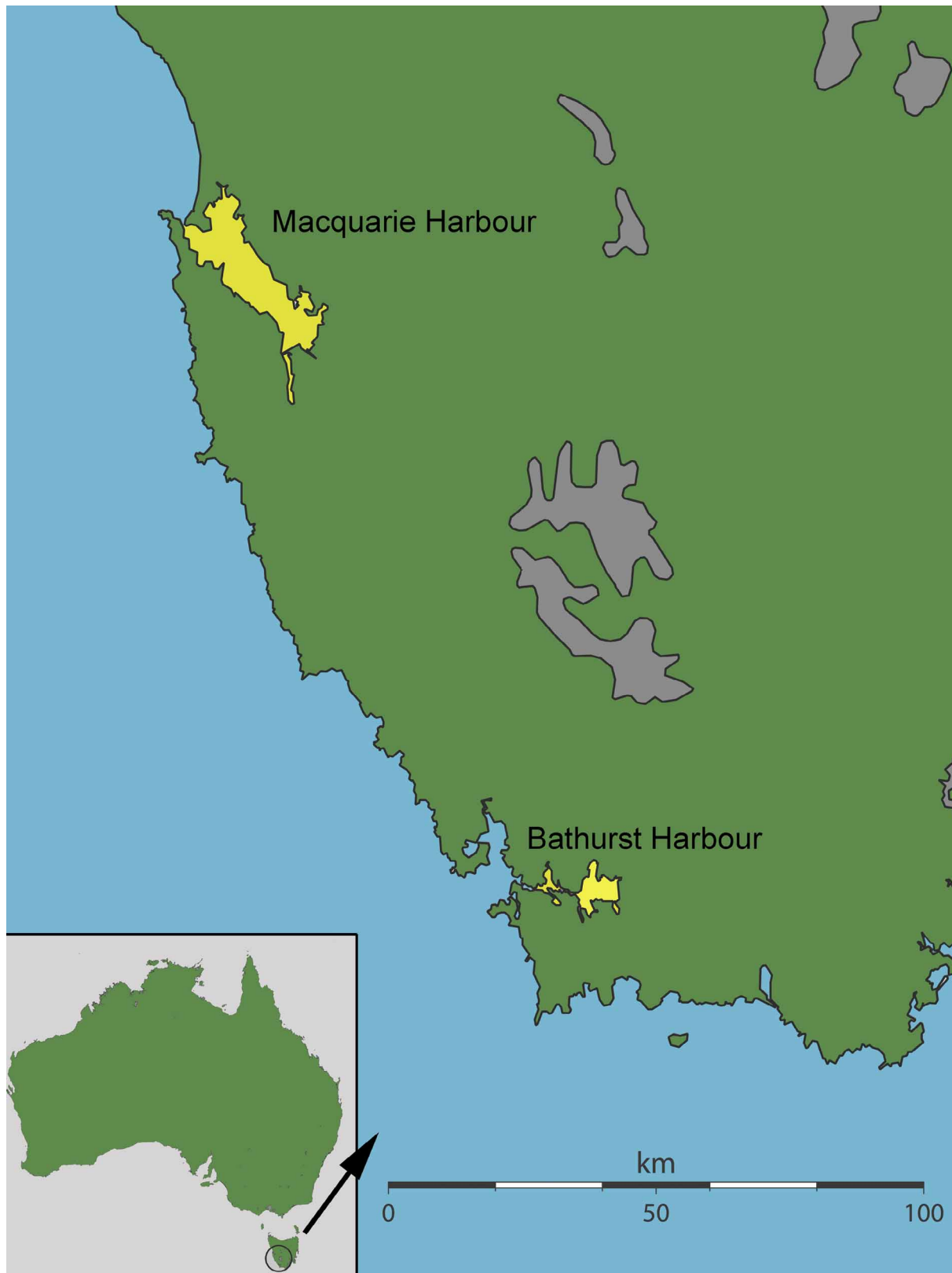

FIGURE 1. Distribution of the new estuarine species of *Zearaja* at Bathurst and Macquarie Harbours, southwestern Tasmania.

In the spring of 1988, then Tasmanian University ecologist, Graham Edgar, conducted a preliminary biological and hydrological survey of the region. Using a gill net, he collected an unidentified long-snouted skate from brackish water in Bathurst Harbour. Unfortunately, the specimen was discarded. Of the 228 or so species of skates known world-wide at the time (McEachran & Miyake 1990), all were considered to be marine. In Tasmania, only *D. lemprieri* had been observed or caught in estuaries (including the Port Davey system), and then only in fully marine habitats at the estuary mouth. Furthermore, all four species of *Dipturus* known from the continental shelf of Tasmania were short-snouted species. Observations on local skate distributions were based on a decade of marine resource surveys and comprehensive data from commercial fishery catches, so the collection of an unidentified coastal skate so far into brackish water was puzzling.

In February the following year, Edgar returned to Port Davey and was able to collect a second specimen also using a gill net. The 706 mm TL mature male was indeed long-snouted and differed from all other inshore skates, being morphologically similar to local deepwater *Dipturus* species, *D. gudgeri* (Whitley 1940) and *D.* sp. J (*sensu* Last and Stevens 1994) from the adjacent continental slope. This skate, subsequently referred to as the Maugean skate, *Raja* sp. L (*sensu* Last and Stevens 1994), does not seem to be common in the Port Davey estuary. Only two more specimens have ever been collected and one more observed by divers, all from the dark tannic brackish waters of Bathurst Harbour, despite considerable survey effort over the next few years and more than 100 hours of underwater observation.

Fortunately, the Maugean skate is not confined to Bathurst Harbour. Macquarie Harbour, a large estuarine bay immediately to the north of Port Davey, also has large expanses of tannin stained, oligohaline brackish water at its inland extremity. In July 1994, CSIRO technician Mark Lewis, collected 5 more specimens (of which only one was retained) in almost total freshwater in the upper reaches of this estuary. The species appears to be more abundant and widespread in Macquarie Harbour than Port Davey. Specimens have also been collected near the harbour entrance but have not been taken from fully marine habitats nearby. Only nine individuals reside in biological collections in Australia and another 14 specimens have been collected by postgraduate, M. Treloar for ecological research. Consequently, given the relatively narrow geographic range of the Maugean skate and its apparent small population, it has raised serious conservation concerns. It has now been listed as Endangered in the IUCN 2000 Red List assessment (Cavanagh *et al.* 2003), by the Australian Environment and Biodiversity Conservation Act (Commonwealth Department of the Environment and Heritage 2006), and by the Tasmanian Government (Department of Primary Industries and Water 2006).

The Maugean skate belongs to a group of skates that includes *Raia chilensis* Guichenot, 1848, and *Raja nasuta* Müller and Henle 1841. These nominal species have been assigned to the genus *Dipturus* Rafinesque by McEachran and Dunn (1998) but conform more closely to the currently unrecognised genus, *Zearaja* Whitley. In the following paper, the Maugean skate is formally described, the genus *Zearaja* resurrected, and its possible origin and relationships to other *Dipturus*-like skates briefly discussed.

Materials and methods

External measurements and the descriptive format were based on McEachran and Fechhelm (1982). However, the following measurements and counts are sometimes recorded using slightly different methods and require clarification: measurements to the cloaca were taken from the first or second haemal spine as described by Hubbs and Ishiyama (1968); snout to spiracle is taken from the snout tip to the rear of the aperture of the spiracle (rather than the front); spiracular length is measured across the widest point of the main opening and does not include the surrounding depression; ventral snout length (pre upper jaw) is taken from the snout tip to the skin edge overlaying the upper jaw at its symphysis; pelvic-fin lobe lengths were measured from the point of articulation of the anterior lobe (Stehmann 1985); total width of the nasal curtain was measured as the maximum width across the curtain posterior to the nostrils; and mouth width was taken as the exposed width of the

upper jaw between the overlaying lateral skin folds (rather than the width across the jaws). Body measurements, expressed as a percentage of total length (TL), are provided in tables; data for six paratypes are provided in parentheses after data for the holotype; two paratypes (CSIRO H 1987–01, AMS I 40748–01) are badly bent and were not used for morphometrics. Radiographs of additional material were used to support observations made from dissections and to obtain counts of the tooth rows, vertebrae, and pectoral and pelvic-fin radials. Propterygial and metapterygial counts each include all radials branching from the main supporting cartilages but exclude the distal element which can appear as a truncated cartilage or as a fin ray. Vertebral counts were made using methods described by Hubbs and Ishiyama (1968); trunk counts include only whole centra (the anteriormost element is often fragmented). Other methods for counts and measurements, with few exceptions, follow standard practices: clasper terminology followed Stehmann (1970; 1976) and Hulley (1972). Materials examined are deposited in ichthyological collections of the Australian National Fish Collection, Hobart (CSIRO), the Australian Museum, Sydney (AMS), the Hokkaido University, Hakodate (HUMZ), and the Museum National d'Histoire Naturelle, Paris (MNHN).

Results

Family Rajidae
***Zearaja* Whitley 1939: 254**
Type species: *Raja nasuta* Müller and Henle 1841. Type by original designation.

Diagnosis

Rajin genus defined by the following combination of characters: clasper greatly enlarged in mature males, its length 24–32% TL; apex of clasper broadly spatulate, its width 6–8 in clasper length; shield relatively broad and short (its length 3.7–4.7 in length of glans), capable of extended ventro-lateral rotation, situated proximally (its length shorter than post-shield length of glans); glans oblique to clasper shaft when closed, extremely everted when open; dorsal lobe of clasper greatly thickened at dorsal terminal 2; ventral terminal cartilage with deep proximal groove enabling loose articulation with ventral marginal cartilage; rhipidion reduced, not stout and fleshy; sentinel and funnel absent; spike concealed by integument, its tip producing a triangular skin fold; distal inner portion of dorsal marginal cartilage forming a twisted, flag-shaped pseudorhipidion.

Definition

Long-snouted skates with a quadrangular disc; tail short, 37–46% TL, not expanded at its midlength; dorsal fins close together near tail apex; orbit large, 3–7 in snout length; exhibiting varying levels of sexual dimorphism in some shape characters, in particular of the snout length, head width and length, and elements of the pelvic fin; no terminal process at tip of snout; dorsal surface largely naked or with weak covering of fine denticles; orbital thorns present; thorns present along dorsal midline of tail, additional row along each lateral in males, additional 2 rows along lateral margin in large females; alar thorns depressible into grooves; malar thorns lateral to eyes; rostral shaft firm, robust, stout proximally, uncalcified apically; anterior fontanelle of neurocranium without distinct anterior margin; rostral appendices not evident from radiographs; scapulocoracoid moderately expanded, lacking anterior bridge, postdorsal fenestra greatly expanded, one postventral fenestra; propterygium of pectoral girdle extending into about a third of pre-nasobasal space; clasper glans of relatively simple construction (Figure 2); no external pseudosiphon; components cleft, pseudorhipidion, and sentina present; clasper skeleton with 3 dorsal terminal cartilages (Figure 3); one accessory terminal cartilage, and ventral terminal of group-typical shape; shield with pleated lamellae in its inner surface, with a strong mesial ridge forming a dike distally; median ridge of ventral terminal clasper cartilage weakly developed, not extended to form a funnel; ventral surface of disc light or dark, pores dark-edged; pectoral radials 78–86; trunk centra 29–34; predorsal caudal centra 52–61.
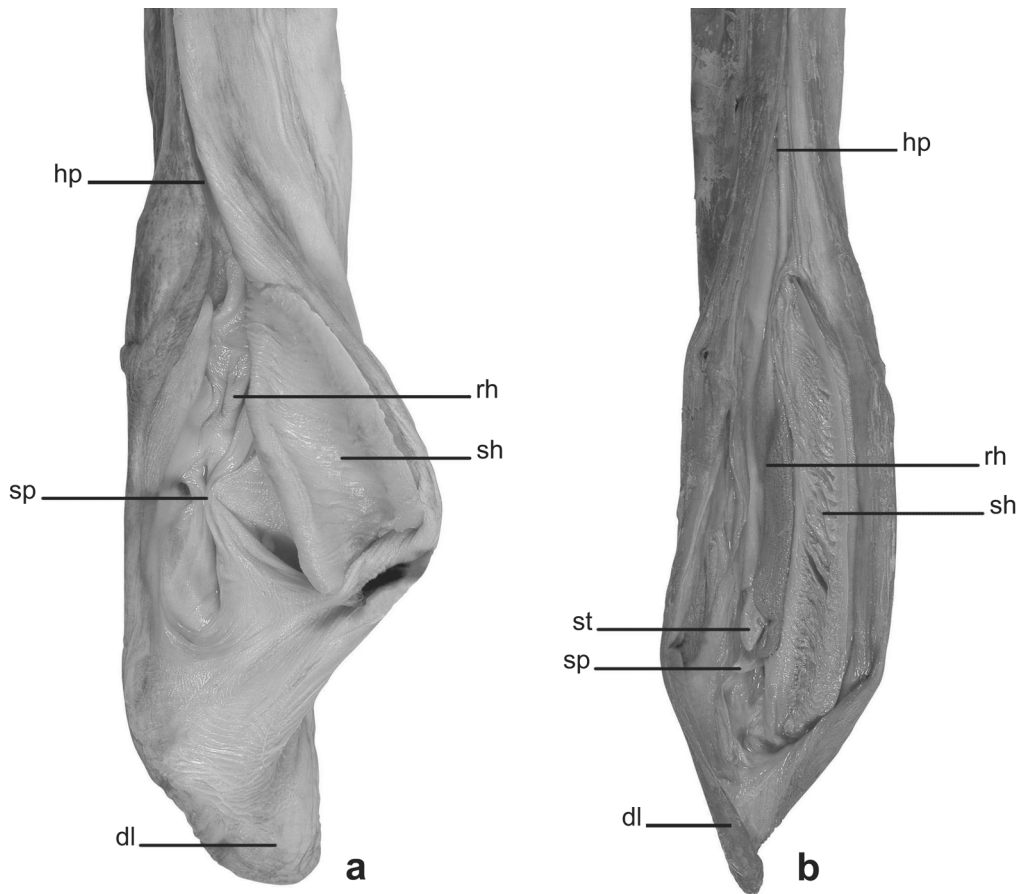
FIGURE 2. Lateral view of right claspers of: a—*Zearaja nasuta*, CSIRO H 5886–01, specimen not retained; b—*Dipturus gudgeri*, CSIRO T 2007–01, 1170 mm TL. Clasper terminology abbreviated as: dl—distal lobe, rh—rhipidion, st—sentinel, sh—shield, sp—spike.
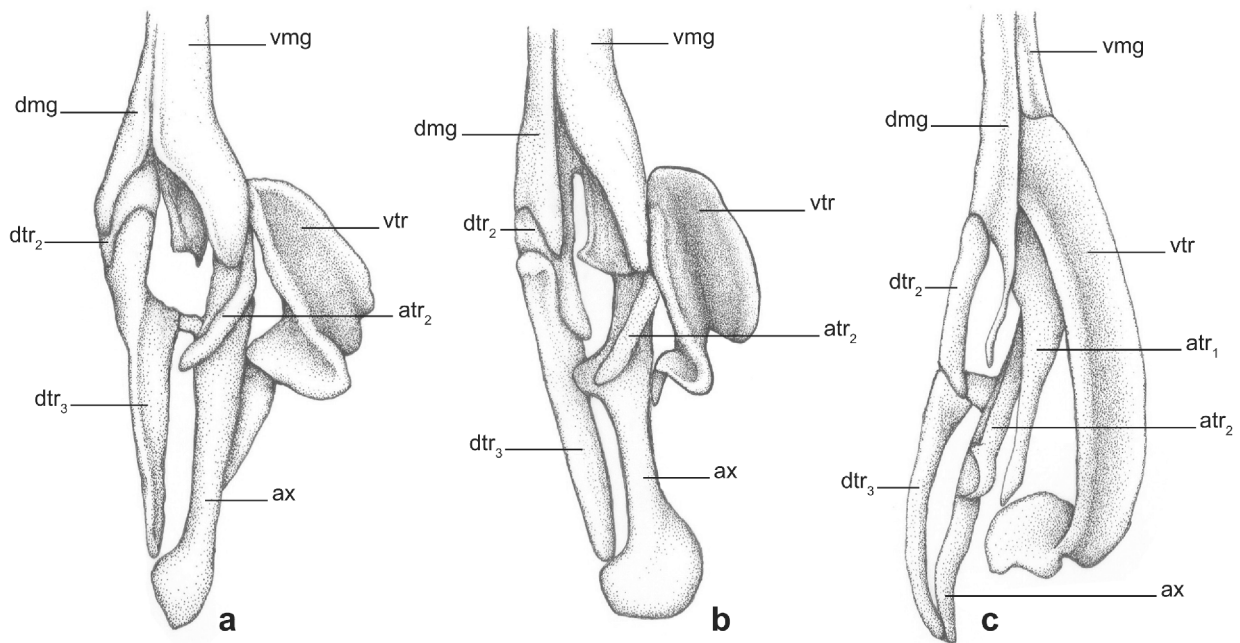

FIGURE 3. Lateral views of the clasper skeletons of: a—*Zearaja nasuta*, NMNZ P 2843, 570 mm DW, right clasper; b—*Zearaja chilensis*, CSIRO H 5298–01, 990 mm TL, left clasper (image reversed for ease of comparison); c—*Dipturus* sp. A, CSIRO unregistered, no data recorded, right clasper. Skeletal terminology abbreviated as: atr_1—accessory terminal 1 cartilage, atr_2—accessory terminal 2 cartilage, ax—axial cartilage, dmg—dorsal marginal cartilage, dtr_2—dorsal terminal 2 cartilage, dtr_3—dorsal terminal 3 cartilage, vmg—ventral marginal cartilage, vtr—ventral terminal cartilage.

Composition

The genus *Zearaja* presently consists of at least three valid species: *Z. nasuta* from throughout New Zealand (Ayling & Cox 1982; Paul 2000), including the Challenger, Bounty and Campbell Plateaus, and the Chatham Rise (Francis *et al*. 2001); *Z. chilensis* in the SE Pacific from 30°15'–55°13'S, and the SW Atlantic from 34°35'–55°S (Licandeo *et al*. *in press*); and the undescribed species treated herein from cold temperate, southern Australia (formerly *Raja* sp. L *sensu* Last and Stevens 1994). *Raja stabuliforis* Garman, from the western North Atlantic, was erroneously placed in synonymy with *Zearaja chilensis* (Guichenot 1848) by Lloris and Rucabado (1991). Based on clasper morphology, it is more likely to belong to *Dipturus* than *Zearaja* and *D. laevis* (Mitchill) is a likely senior synonym.

Nevertheless, other *Zearaja* species may exist. *Zearaja nasuta* varies greatly in colour, from uniformly brownish or grey, to having strong patterns of spots and blotches. This species also appears to be unusually eurybathic for an Australasian skate, occurring from coastal habitats to at least 658 m depth on the continental slope (NMNZ data). Forms from the New Zealand continental shelf and slope were compared morphometrically. Females and males from each region differed from each other in several characters but there were some interregional differences in tail morphology. The tail of the slope form appears to be more robust (tail width at mid-length 3.4–3.9 vs. 2.9–3.4% TL; tail width to height ratio at midlength 2.06–2.40 vs. 1.76–2.05; and tail width at first dorsal-fin origin 2.7–3.2 vs. 2.2–2.9% TL), and the disc is relatively broader (disc width to length ratio 1.17–1.22 vs. 1.15–1.17). Populations of *Z. nasuta* from New Zealand need to be more carefully examined and this work should be coupled with the use of a molecular study. Similarly, the South American skate, *Z. chilensis*, is thought to occur in the SE Pacific, as well as the SW Atlantic where it was formerly known as *D. flavirostris* (Philippi). However, there are regional differences in *Z. chilensis* populations, even in Chile. Leible (1987) examined females with abnormal spination, and some male specimens that were late maturing (890–940 mm TL rather than 750–850 mm TL), so these populations also need further investigation.

TABLE 1. Morphological differences between the claspers of *Zearaja nasuta* and *Dipturus* species (*D. batis* and *D. gudgeri*). Skeletal terminology abbreviated as: Atr_1—accessory terminal 1 cartilage, Dtr_1—dorsal terminal 1 cartilage, Dtr_2—dorsal terminal 2 cartilage, Vmg—ventral marginal cartilage, Vtr —ventral terminal cartilage.

Zearaja	*Dipturus*
Shield very short, robust, capable of extended rotation	Shield very long and slender, capable of minor rotation
Atr_1 and sentinel absent	Atr_1 usually Y-shaped or broadly united with Vmg, sentinel well developed
Spike concealed by integument, immobile	Spike exposed, mobile
Distal lobe of clasper extremely spatulate	Distal lobe of clasper narrowly rounded or pointed
Distal limb of Vtr free of axial, connected along the inner lateral margin to Dtr_1	No equivalent extending limb or connection
Pseudorhipidion truncate distally, flag-shaped	Pseudorhipidion pointed and flexible
Dtr_2 very short and strong	Dtr_2 relatively elongate

Remarks

Zearaja was nominated by Whitley (1939) for *Z. nasuta* based on its produced snout, elevated pectoral girdle, rough disc, thorn distribution, and dark-edged ventral pores. These characters also apply to members of several other rajin genera so it is unsurprising that members of the genus *Zearaja* have been consistently placed in synonymy with *Dipturus* (for example Stehmann 1990; Compagno 2005), the members of which they superficially resemble. Last and Yearsley (2002) resurrected *Zearaja* to subgeneric status within *Dipturus* but suggested that the group is more likely to be generically distinct. The external morphology, neurocranium, pelvic girdle and scapulocoracoid of these taxa are of a similar type but major differences exist in

TABLE 2. Morphometric values demonstrating sexual dimorphism in *Zearaja nasuta*; mature males (MM, n=4), immature males (IM, n=4) and females (F, n=3). Values are expressed as a percentage of total length.

	Z. nasuta MM		*Z. nasuta* IM		*Z. nasuta* F	
	min	max	min	max	min	max
Total length (mm)	751	850	540	655	625	771
Disc width	66.5	70.3	68.6	75.4	70.4	77.2
Disc length (direct)	56.8	60.3	59.1	63.1	61.6	63.4
Snout to maximum width	33.4	36.9	34.3	39.3	38.0	42.8
Snout length (preorbital direct)	14.7	17.0	18.2	19.4	20.1	22.0
Snout to spiracle	20.2	22.5	23.2	24.7	25.3	27.2
Head (dorsal length)	22.3	25.0	25.0	27.1	27.6	29.2
Orbit diameter	3.5	4.4	3.5	4.1	3.5	4.2
Orbit and spiracle length	5.4	5.9	5.1	5.5	5.5	5.7
Spiracle length (main pore)	1.6	2.2	1.7	2.0	2.0	2.2
Distance between orbits	5.0	5.8	4.9	5.8	5.7	6.0
Distance between spiracles	7.0	7.3	6.6	7.4	7.4	7.5
Distance-snout to cloaca	54.7	58.4	56.4	58.8	58.7	61.9
Distance-cloaca to caudal-fin tip	42.2	44.6	40.9	43.9	37.8	40.4
Ventral snout length (pre upper jaw)	15.1	16.7	17.6	18.8	19.5	21.7
Prenasal length	13.6	15.5	16.1	16.8	17.5	19.7
Ventral head length (to fifth gill)	31.1	32.9	33.2	35.2	34.7	36.9
Mouth width	7.9	9.5	8.8	9.9	9.0	9.9
Distance between nostrils	8.5	10.1	8.9	9.4	9.3	9.7
Nasal curtain length	4.6	5.5	4.8	4.9	5.1	5.3
Nasal curtain (total width)	10.0	11.2	9.7	10.6	10.0	10.8
Nasal curtain (min. width)	6.5	7.9	6.8	7.3	7.1	7.7
Nasal curtain (lobe width)	2.2	2.4	2.1	2.2	2.2	2.4
Width of first gill opening	1.5	1.7	1.3	1.7	1.5	1.7
Width of fifth gill opening	1.2	1.4	1.2	1.3	1.2	1.4
Distance between first gill openings	14.5	15.9	14.6	16.9	16.6	17.3
Distance between fifth gill openings	8.3	8.9	9.1	9.9	10.2	11.5
Clasper (post cloacal length)	25.9	29.5	12.1	20.5	0.0	0.0
Length of anterior pelvic lobe	12.9	14.2	13.4	14.4	12.2	14.0
Length of posterior pelvic lobe	20.5	23.2	18.3	19.5	16.1	18.3
Pelvic base width	8.3	9.0	7.9	9.6	9.9	10.4
Tail at axil pelvic fins (width)	4.4	5.6	4.5	5.2	4.8	5.8
Tail at axil pelvic fins (height)	2.7	2.9	2.3	2.7	2.4	2.7
Tail at midlength (width)	3.2	3.9	2.9	3.7	2.9	3.6
Tail at midlength (height)	1.6	1.8	1.6	1.8	1.5	1.7
Tail at D1 origin (width)	2.7	3.2	2.2	3.0	2.7	3.2
Tail at D1 origin (height)	1.4	1.6	1.3	1.6	1.3	1.5
D1 base length	4.9	5.6	5.4	6.1	4.5	5.6
D1 height	3.4	3.9	3.1	3.5	2.7	3.4
D1 orig to caudal-fin tip	13.2	16.9	14.2	15.7	12.9	14.5
D2 orig to caudal-fin tip	6.8	10.2	8.2	9.0	6.9	8.1
Caudal-fin length	2.4	3.9	3.0	3.6	2.3	4.2

clasper morphology (Table 1). *Dipturus* species, including the type species *D. batis* (Linnaeus) based on data from Stehmann (1970), typically have both a spike (formed from the distal tip of the accessory terminal 2 cartilage) and a sentinel (formed from the distal tip of the accessory terminal 1 cartilage). In *Zearaja*, the clasper skeleton is comparatively simple and one accessory terminal cartilage is missing. Leible's (1987) figure of the clasper of *Z. chilensis* (as *Raja (Dipturus) flavirostris*) shows an accessory terminal 1 cartilage present with the accessory terminal 2 cartilage missing. However, in our material of the three *Zearaja* species, the accessory terminal cartilage arises on the inner lateral margin of the ventral marginal cartilage, in the position equivalent to the accessory terminal 2 cartilage in both *Dipturus gudgeri* and *D.* sp A. The accessory terminal 1 cartilage arises in the median ventral axis in all *Dipturus* species examined, as well as *D. batis* (Stehmann 1970). No equivalent structure exists at this location in *Zearaja*. Hence, based on the position of this cartilage, we consider this element to be more akin to the accessory terminal 2 cartilage than the accessory terminal 1 cartilage, and its terminal element should be called the spike rather than the sentinel (*sensu* Leible 1987).

Zearaja claspers also are capable of much greater rotation of the shield than *Dipturus*. In *Zearaja,* this structure is relatively more robust and shorter (clasper length more than 3.5 vs. less than 2.5 times shield length in *Dipturus*), and is situated well away from the clasper apex (length of clasper distal to shield exceeding length of shield vs. than less than half length of shield). The long post-shield section of the glans in *Zearaja*, which terminates in a broadly spatulate distal lobe, is unlike any *Dipturus* species. The claspers of other rajin genera are more complex and all have an accessory terminal 1 cartilage and sentinel.

The internal morphology of the clasper glans in *Zearaja* changes dramatically when the clasper is fully everted. The shield and posterior glans are capable of a rotation in excess of 90º to the axis of the clasper shaft. In this condition, the cleft between the dorsal marginal cartilage and dorsal terminal cartilages has a greatly increased volume. The spike, which is covered in integument, becomes visible against a thickened portion of the axial cartilage. The truncate distal ventral marginal cartilage extends more posteriorly into the central glans. Union of the dorsal terminal 2 and dorsal terminal 3 cartilages at the disto-lateral margin of clasper are broken with the proximal limb of the dorsal terminal 3 cartilage projecting beneath external integument as a spatulate limb. Similarly, the proximal half of the dorsal terminal 1 cartilage forms a cover that projects prominently through the external integument.

Sexual dimorphism in shape is evident in *Z. nasuta* in material from both the continental shelf and slope (Table 2). The disc is relatively wider (70.4–77.2 vs. 66.5–70.3% TL) and longer (61.6–63.4 vs. 56.8–60.3% TL), and the preorbital (20.1–22.0 vs. 14.7–17.0% TL), prespiracular (25.3–27.2 vs. 20.2–22.5% TL), and head (27.6–29.2 vs. 22.3–25.0% TL) lengths longer, in adult females than in mature males. Similar trends exist for ventral head, intergill, pre upper jaw, and prenasal lengths. The pelvic-fin base is relatively broader in females (9.9–10.4 vs. 8.3–9.0% TL) but the posterior pelvic-fin lobe is shorter (16.1–18.3 vs. 20.5–23.2% TL). There also appears to be a minor difference in the first dorsal-fin height being slightly shorter in females (2.7–3.4 vs. 3.4–3.9% TL).

Zearaja maugeana sp. nov.
Figs 4–12; Table 3

Raja sp. L Last and Stevens, 1994: 339, fig 34.27, pl. 55.

Holotype
    CSIRO H 3975–01, 659 mm TL, mature male, Macquarie Harbour, Australia, 42°21′ S, 145°32′ E, 25 June 1995, D. Haslam.

Paratypes
    CSIRO H 1987–01, 706 mm TL, mature male, Bathurst Harbour, Australia, 43°21′ S, 146°08′ E, 12 February 1989, G. Edgar; AMS I 40748–001, 682 mm TL, mature male, Bathurst Harbour, Australia, 43°21′ S,

146°08′ E, 27 May 1989, G. Edgar; CSIRO H 5544–01, 725 mm TL, female, Bathurst Harbour, Australia, 43°22′ S, 146°09′ E, 29 March 1992, J. Stevens & P. Mooney; CSIRO H 3747–01, 578 mm TL, female, Macquarie Harbour, Australia, 42°23′ S, 145°27′ E, 30 July 1994, M. Lewis; CSIRO H 3976–01, 571 mm TL, female, CSIRO H 3976–02, 770 mm TL, female, Macquarie Harbour, Australia, 42°24′ S, 145°30′ E, 17 June 1995, M. Lewis & D. Haslam; CSIRO H 4486–01, 685 mm TL, adolescent male, Macquarie Harbour, Australia, 42°12′ S, 145°18′ E, 3 September 1995, B. Zampatti; CSIRO H 4487–01, 744 mm TL, female, Macquarie Harbour, Australia, 42°16′ S, 145°15′ E, 3 September 1995, B. Zampatti.

FIGURE 4. *Zearaja maugeana* sp. nov., holotype, CSIRO H 3975–01, 659 mm TL, mature male: a—dorsal surface; b—ventral surface.

FIGURE 5. Dorsal surface of *Zearaja maugeana* sp. nov., paratype, CSIRO H 3976–02, 770 mm TL, female.

FIGURE 6. Ventral view of *Zearaja maugeana* sp. nov., holotype, CSIRO H 3975–01, 659 mm TL, mature male, showing oronasal region and tooth band.

Diagnosis

A relatively small species of *Zearaja* with the following combination of characters: granular denticles absent or poorly developed on dorsal surface of pectoral disc, disc width 67–71% TL, 1.09–1.12 times its length; pre upper jaw length 20.6–24.7% TL; ventral head length 36.1–38.8% TL; adult clasper relatively

short, 23.9–26.8% TL; tail evenly tapering, not robust, height at midlength 1.3–1.4% TL; snout length 3.75–4.38 times interorbital width; pre upper jaw length 2.20–2.58 times internasal width; orbit diameter 0.58–0.69 of interorbital width; total pectoral radials 78–85; predorsal vertebrae 85–93; teeth in upper jaw 38–43.

DESCRIPTION.— Disc quadrangular (Figures 4, 5), 1.12 times as broad as long in holotype (1.09-1.12 times in paratypes); maximum angle in front of spiracles 71° (68-72°); axis of greatest width 62% (60-69%) of disc length; anterior margin weakly double concave (slightly less pronounced in females), strongly concave anteriorly, straight to weakly convex beside eyes, slightly concave behind level of spiracles in holotype; apex narrowly rounded; free rear tip broadly rounded. Head elongate, preorbital snout length 5.80 (5.71-6.69) times orbit length, 3.75 (3.87-4.38) times interorbit; preoral snout length 2.20 (2.30-2.58) times internarial distance. Snout tip produced, narrowly pointed; no fleshy process at apex. Orbit well developed, diameter 0.65 (0.58-0.69) times interorbital distance; eye lateral; deep subocular furrow extending from origin of orbit to spiracle (not evident in some paratypes). Spiracle large, length 1.70 (1.61-2.01) in orbit diameter; opening broadly suboval. Nostril subcircular (Figure 6), often distorted or oval in some paratypes; anterior nasal flap expanded slightly; lateral margin of nostril with a well-defined lobe forming a semi-circular tube, anterior margin also lobe-like, concealed beneath nasal curtain; inner margin bordered by nasal curtain; posterior lobes forming nasal curtain, well developed, produced, narrowly rounded to angular distally, with well developed fringe along posterior margin; internarial distance 1.73 (1.65-1.76) in distance between first gill slits, 0.97 (0.96-1.14) in distance between fifth gill slits. Upper jaw arched slightly on either side of symphysis in holotype, not indented in females; lower jaw more uniformly convex in both sexes; lateral teeth concealed by lobe of nasal curtain. Teeth unicuspid with subcircular bases; arranged in distinct longitudinal rows rather than quincunx; in mature males, with long, upright medial cusps at symphysis, cusps becoming shorter, more oblique laterally (variable, but more robust and generally more upright in female paratypes); teeth at angle with very short cusps.

Pelvic fins strongly forked; anterior lobe short, slender, narrowly rounded distally, lateral margin entire, inner margin moderately incised; posterior lobe very elongate, relatively longer in males (length 20.3% TL) than in females (length 13.9–16.0% TL), lateral margins moderately convex, inner margin almost straight; anterior lobe 0.65 in mature male holotype (0.69 in mature male paratype, CSIRO H 4486–01; 0.73–0.83 in female paratypes) times posterior lobe. Tail depressed, moderately broad at base, barely tapering to first dorsal-fin origin (female paratype, CSIRO H 3747–01, with badly shrivelled tail); tapering strongly to tip behind first dorsal fin; width at insertions of pelvic fins 1.30 (1.32–1.53) times width at midlength of tail and 1.57 (1.34–1.72) times width at first dorsal-fin origin respectively; length from rear of cloaca 0.69 (0.60–0.72) times distance from tip of snout to rear of cloaca; anteriorly cross-section weakly convex dorsally and ventrally, becoming more strongly convex on dorsal surface than ventral surface posteriorly, almost flat ventrally toward tail apex; width 1.60 (1.26–1.69) times height at insertion of pelvic fin, 2.25 (1.89–2.27) times height at midlength, 1.99 (1.93–2.10) times height at first dorsal fin origin; lateral skin fold well developed, originating about an orbit diameter behind pelvic-fin insertion, extending almost to tail tip, not becoming appreciably broader distally. Dorsal fins large (Figure 7), of similar shape and size, first dorsal fin slightly more upright than second; first dorsal-fin height 1.47 (1.32–1.70) in base length; fins strongly raked, low, elongate, with long bases; anterior margins weakly convex, apices broadly rounded, posterior margins convex, free rear tip narrowly rounded to acute; inner margin of first dorsal longer than second; interdorsal distance short, 3.58 (3.3–8.2) in length of first dorsal-fin base. Epichordal caudal-fin lobe well developed, height about equal to half tail width at fin origin; usually taller posteriorly than anteriorly; usually truncate distally, dorsal margin straight or weakly convex; connected sub-basally to second dorsal fin; hypochordal caudal lobe vestigial.

Dorsal surface with well-developed nuchal, orbital, tail, malar and alar thorns in adult males; no thorns along most of mid-disc or on scapular region; denticles concentrated on tail, around orbits, on snout tip, and along anterior margin and middle of disc; pectoral fin mostly naked in males, scattered minute denticles present in largest female (CSIRO H 3976–02). Orbital thorns forming a rosette, variable in size, often barely

larger than surrounding denticles; 7–8 in holotype (2–3 on preorbit, 2 on midorbit and 2–3 on postorbit), 5–13 in paratypes; low, slender, directed posteriorly, recurved. Nuchal thorns 2 (0–3 in paratypes, mainly 2), widely spaced; somewhat laterally compressed, otherwise subequal in size and similar in shape to largest orbital thorns. Malar thorns 4–7 (about 8–15 in adult male paratypes), all lateral to orbit; forming a single, weakly curved series (two thorns paired on left side of holotype), in 2–4 irregular series in paratypes; mostly subequal in size and similar in shape to each other and largest orbital thorn; directed posterolaterally. Alar thorns 18–20 (including missing thorns), 16–28 in paratypes, well developed, longer than other thorns; embedded, tips pungent, directed postero-medially in 2–3 irregular rows. Tail thorns well developed, in three regular rows in males (Figure 8), 5 regular rows in largest females. Median row best developed of these, commencing on dorsal disc just forward of cloaca and extending along length of tail in a single series; with 27 (up to 45 in paratypes) pungent, recurved or upright thorns with large bases, slightly larger than largest orbital thorn; 10 much smaller interstitial thorns interspersed with these larger thorns, interstitial thorns present on both sexes; interdorsal thorn 1 (1–3 in paratypes). Lateral rows in males short, with 8–9 (6–13) thorns (interstitial thorns absent); located closer to lateral skin fold than to thorns of median thorn row; commencing from above pelvic fins and extending along tail to between tail midlength and dorsal fins; thorns similar in size and shape to largest median thorns; in females, additional lateral row bordering lateral skin fold, upper lateral row shortest, originating and terminating more anteriorly than lower lateral row, lower lateral row terminating under dorsal fins; largest females with a few isolated mid dorsal thorns.

FIGURE 7. Lateral view of dorsal and caudal fins of *Zearaja maugeana* sp. nov., holotype, CSIRO H 3975–01, 659 mm TL, mature male.

a

b

FIGURE 8. Denticles at tail midlength of *Zearaja maugeana* sp. nov., holotype, CSIRO H 3975–01, 659 mm TL, mature male: a—dorsal view; b— lateral view.

Denticles generally not well developed; patches on head confined to snout tip, preorbit, interorbit and interspiracular regions (very weakly developed in smallest paratype); narrow band of minute, widely spaced denticles extending along dorsal midline from nuchal region to tail tip. Anterior mid-dorsal band triangular in shape anteriorly, extending from anterior nuchal thorn across scapular region, its maximum width equivalent to interspiracular width; band tapering gradually posteriorly, its width subequal to tail width at pelvic-fin insertions, sharply defined from naked lateral disc adjacent; band covering most of dorsal tail to its tip. Denticle band on margin of disc well developed, originating at about level of front of eye and extending along disc margin almost to level of anterior alar thorns in males (less well developed in females, absent in smallest specimen CSIRO H 3976–01); band broadest near posterior malar thorns; denticles much larger and denser than those of mid-disc. Denticles of mid-disc and unpaired fins very small, granular, widely spaced on mid-disc; densest near dorsal-fin outer margins, at snout tip, adjacent orbit, and along disc margin; those on snout tip and around orbit slightly enlarged; a few small denticles along margin of rostral cartilage; mid-disc preceding first nuchal thorn, suborbit, orbital membrane, pelvic fins, claspers and most of pectoral fins naked (largest females with scant covering of denticles on suborbit, and pelvic and pectoral fins). Ventral surface mostly naked; denticle patches confined to head forward of mouth and along margin of disc; posterior extension and width of marginal band similar to that of dorsal marginal band; a few isolated denticles present on tail.

Rostral cartilage of neurocranium (Figure 9, based on radiograph) elongate, slender; rostral appendix indistinct from radiographs; nasal capsule elliptical in shape and set at about 20° angle to transverse axis of neurocranium; anterior fontanelle relatively long and broad, with distinct anterior margin preceded by gentle groove in rostral shaft; posterior fontanelle moderately long, not constricted posteriorly; jugal arch robust. Scapulocoracoid (Figure 10, based on mature male paratype CSIRO H 1987–01) with moderately expanded lateral face, particularly at procondyle; anterior bridge absent; mesocondyle horizontally expanded; distance between pro- and meso- much less than distance between meso- and metacondyles; anterior fenestra oval, expanded vertically; postdorsal fenestra subcircular; postventral fenestra oval, expanded horizontally, much smaller than postdorsal fenestra. Propterygium of pectoral girdle with anterior tip well short of rostral tip. Pelvic girdle with slightly arched puboischiadic bar with moderately long lateral prepelvic processes (Figure 11); 2–3 orbturatorial foramina, iliac process well developed.

Clasper long, rather robust, not depressed or tapering distally, without dermal denticles or pseudosiphon; strongly oblique to main axis of cartilage, directed postero-mesially (most pronounced with clasper closed); distal part of clasper beyond glans broad, flattened, spatulate (Figure 12); glans greatly expanded along proximo-lateral margin, dorsal lobe bulbous adjacent end of hypopyle, ventral lobe even more significantly expanded immediately beyond dorsal expansion (visible when viewed dorsally). Shield relatively small, short, its length only slightly more than twice its width; capable of extended ventro-lateral rotation; lateral margin of cartilage exposed, sharp edged, blade-like, strongly convex; ventral surface covered in thick skin fold; fold attached to secondary, less regularly shaped ridge; secondary ridge situated subparallel and ventral to lateral margin of shield; strong dorsal ridge (component dike) situated on proximal portion, forming deep concavity with lateral margin (also forming right angle), concavity filled with thick pleated epithelia. Rhipidion weak, very slender, not wavy, located along inner margin of shield, well removed from lateral margin of glans, terminating as a short point near midpoint of shield. Spike slender, digitiform, obscure, fully concealed by thick skin; its apex forming triangular skin fold in disto-medial part of glans; fold extending laterally to envelope dike, forming deep, blind, posteriorly directed sac (component sentina). Sentinel absent. Hypopyle with an enlarged, truncate extension of the dorsal marginal cartilage (component pseudorhipidion); deep, open-ended cleft located on dorsal lobe distal to beside dorsal margin of pseudorhipidion. Clasper skeleton simple (Figure 13). Terminal bridge weak, knob-like; second, enlarged cleft located beside distal tip of terminal bridge. Dorsal terminal 1 cartilage enveloping proximal region of glans, not riding freely on dorsal surface; connected proximally at inner margin of dorsal terminal 2 cartilage; abutting axial cartilage and distal extension of ventral terminal cartilage on inner lateral margin of glans. Dorsal marginal cartilage expanded distally, extending distally beyond its junction with dorsal terminal 2 cartilage as a flag-shaped tongue; disto-lateral extension

digitiform, overlapping ventro-lateral margin of dorsal terminal 2 cartilage; dorsal terminal 2 cartilage short, very robust, arched laterally, producing proximo-lateral bulge on glans; dorsal terminal 3 cartilage elongate, longer than ventral terminal cartilage and dorsal terminal 2 cartilage, broadest near terminal bridge. Accessory terminal 2 cartilage digitiform, curving evenly dorso-posteriorly, arising from distal end of ventral marginal cartilage on its inner medial margin, its tip proximal to ventral terminal cartilage tip. Ventral marginal cartilage expanded distally, ventro-distal part subtriangular, without accessory terminal cartilage (normal position of accessory terminal 1 cartilage). Axial cartilage tip disc shaped, united distally with dorsal terminal 3 cartilage to form spatulate clasper tip. Ventral terminal cartilage crudely s-shaped in ventral profile; proximal portion dove-tailed into ventral marginal cartilage, articulating at lateral margin of ventral marginal cartilage mesially, articulating by a long, narrow extension of secondary ridge ventrally; connected to axial cartilage distally by narrow, hooked arm, its apex extending slightly beyond distal tip of lateral margin.

FIGURE 9. Dorsal view of chondrocranium of *Zearaja maugeana* sp. nov., paratype, CSIRO H 5544–01, 725 mm TL, female, based on radiograph.
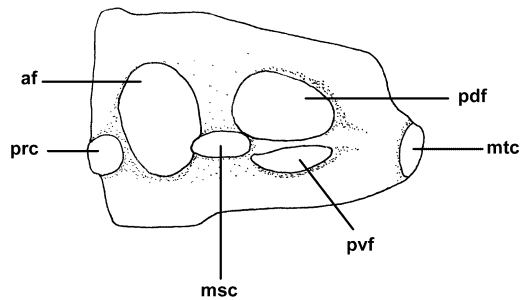
FIGURE 10. Lateral view of scapulocoracoid of *Zearaja maugeana* sp. nov., paratype, H 1987–01, 706 mm TL, mature male. Scapulocoracoid characters are abbreviated as: af – anterior fenestra, msc – mesocondyle, mtc – meta-condyle, pdf – post dorsal fenestra, prc – procondyle, pvf – postventral fenestra.
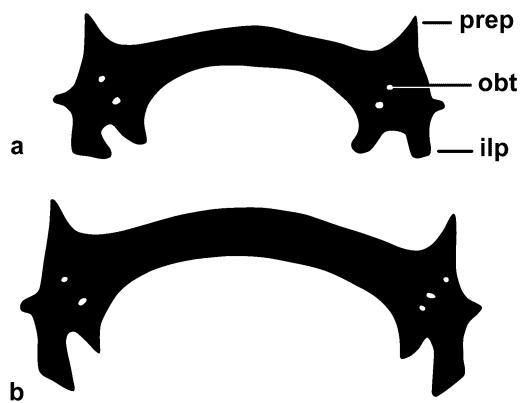

FIGURE 11. Dorsal view of pelvic girdle of *Zearaja maugeana* sp. nov.: a—holotype, CSIRO H 3975–01, 659 mm TL, mature male; b—paratype, CSIRO H 5544–01, 725 mm TL, female. Characters are abbreviated as: ilp—iliac process; obt—obturator foramina, prep—pre-pelvic process.
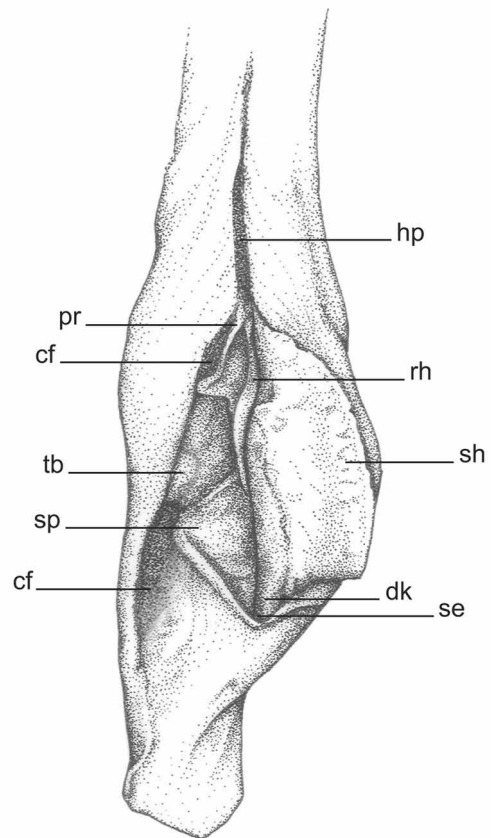

FIGURE 12. Lateral view of right clasper of *Zearaja maugeana* sp. nov., paratype, CSIRO H 1987–01, 706 mm TL, mature male. Clasper terminology abbreviated as: cf – cleft, dk – dike, hp – hypopyle, rh – rhipidion, pr – pseudorhipidion, se – sentina, sh – shield, sp – spike, tb – terminal bridge.

Teeth in upper jaw 43 (38–42); lower jaw 41 (39–42). Pectoral-fin propterygial radials 31 (27–31); mesopterygial radials 15 (14–17), anterior portion 12 (9–13), posterior portion 3 (3–6); metapterygial radials 37 (35–39); total radials 83 (78–85). Monospondylous centra 32 (31–34); predorsal caudal centra 55 (52–61); predorsal centra 87 (85–93); total centra about 148 (144–153).

Colour (In Preservative)

Dorsal surface of disc and tail almost uniformly dark greyish brown (some paratypes more uniformly darker); darkest at pre-orbit and over supraorbit; slightly darker medially on back and along dorsal tail, outer margin of disc paler than central part; lateral snout whitish (less pronounced in some paratypes), rostral carti-lage strongly demarcated from white area adjacent; anterior and posterior parts of orbital membrane pale; inner portion of spiracle whitish; pelvic fin and claspers similar to dorsal disc; dorsal and caudal fins greyish to black; thorns distinct, paler than soft tissue adjacent. Ventral surface with variable markings, with irregular whitish and brownish areas, mostly paler than dorsal surface; most of disc, pelvic fins and tail pale to medium brown, darkest on abdomen, tail, tips of anterior lobe of pelvic fin and in perianal region (sometimes with extensive white areas that extend laterally over pelvic fin bases); prominent black-edged pores over snout, and anterior and central portions of disc, densest on internasal flap and along lower lip, absent from most of belly,

posterior portion of disc and pelvic fins; snout mostly whitish, grading evenly into darker posterior portion of disc (sharply demarcated in some paratypes); granular anterior margin of disc pale, usually sharply demarcated from rest of disc; median snout dusky to almost black; mouth and teeth white; internasal-flap fringe, anterior margin of gill slits, cloaca and origin of pelvic fins whitish.

When fresh: Similar to preserved colour but somewhat darker, almost black dorsally; light and dark areas forming a blotched pattern ventrally, markings variable, strongly contrasted.
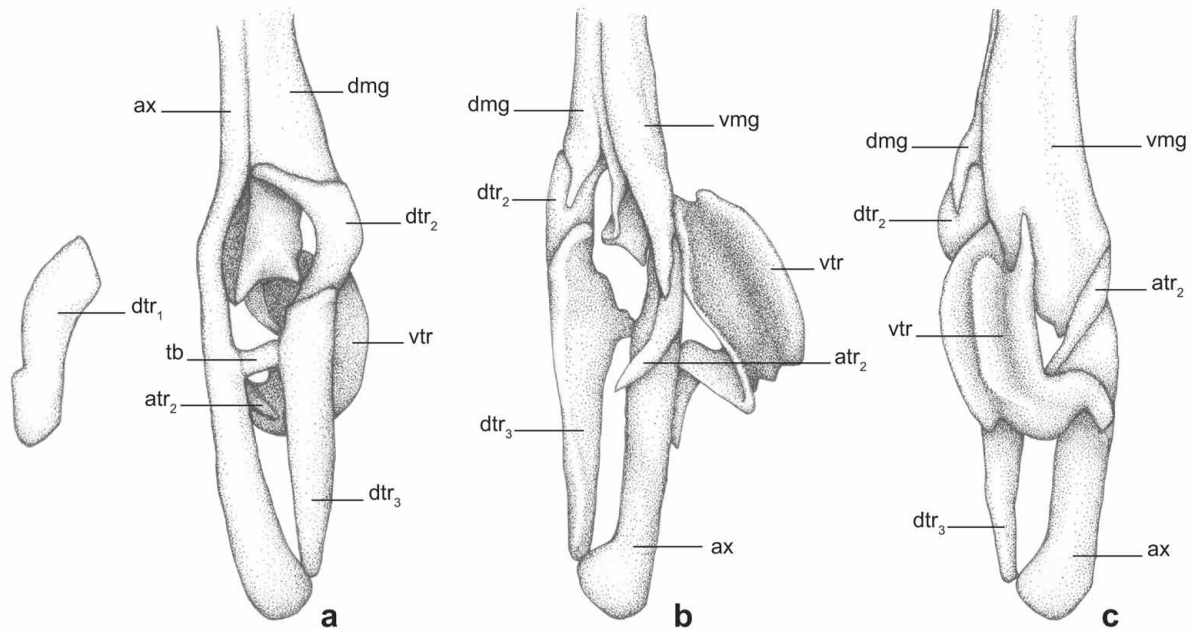

FIGURE 13. Clasper skeleton from right side of *Zearaja maugeana* sp. nov., paratype, CSIRO H 5610–01 (dissected from AMS I 40748–001), 682 mm TL, mature male: a – dorsal view; b – lateral view; c – ventral view. Skeletal terminology abbreviated as: atr_2 – accessory terminal 2 cartilage, ax – axial cartilage, dmg – dorsal marginal cartilage, dtr_1 – dorsal terminal 1 cartilage, dtr_2 – dorsal terminal 2 cartilage, dtr_3 – dorsal terminal 3 cartilage, tb – terminal bridge, vmg – ventral marginal cartilage, vtr – ventral terminal cartilage.

Size

Largest female type was 770 mm TL but known to reach 840 mm TL (Treloar pers. comm.); one male paratype (CSIRO H 4486–01) adolescent at 685 mm TL, but male holotype fully mature at 659 mm TL; mature males ranged between 659–706 mm TL; no information on juveniles or egg cases.

Distribution

Endemic to Bathurst and Macquarie Harbours, in southwestern Tasmania. Occurs primarily in the upper, oligo-mesohaline regions of these estuaries. The total available habitat is less than 300 km² and initial surveys suggest that the population is likely to be less than 1000 individuals (Treloar pers. comm.).

Etymology

The epithet 'maugeana' was derived to draw a link with the Australian cool temperate biogeographic region, the Maugean Province, in which this skate is a keystone species. Its common name, the Maugean Skate, follows this theme.

Ecology and Life History

Unique among extant skates in that it occurs primarily in brackish water. The two estuarine systems in which it lives are high in tannin content with poor light penetration and have silty bottoms. Several deepwater

invertebrate taxa normally found in deep habitats of the continental slope encroach into relatively shallow depths. The snout morphology of this skate, which resembles that of *Dipturus* species found in silty habitats on the continental slope, may be a feeding adaptation. Little is known of other biological or ecological requirements of this recently discovered species. The estuaries are well separated and given that this skate has never been taken in the sea, may form genetically distinct populations. Specimens have been caught in a broad range of brackish salinities to almost fresh water.

Small populations and the geographically restricted distribution of this species have significant conservation implications. The isolation of Bathurst Harbour, which is situated in the heart of large terrestrial and marine parks in southwestern Tasmania, affords partial protection for this species. However, the other remnant population lies in an estuary heavily polluted by prolonged mining operations and anthropogenic interference. Both populations are in otherwise scenic and important recreational areas facing increasing pressure from eco-tourism. *Zearaja maugeana* is also caught occasionally by recreational gill netting in Macquarie Harbour.

TABLE 3. Morphometrics for holotype (CSIRO H 3975–01) and 6 paratypes of *Zearaja maugeana*, sp. nov., 11 specimens of *Z. nasuta*, and 3 specimens of *Z. chilensis*. Values are expressed as a percentage of total length.

	Z. maugeana			*Z. nasuta*		*Z. chilensis*	
	holotype	min	max	min	max	min	max
Total length (mm)	659	571	770	540	850	398	827
Disc width	70.0	66.5	70.5	66.5	77.2	73.9	76.9
Disc length (direct)	62.2	61.0	63.2	56.8	63.4	59.5	63.5
Snout to maximum width	38.8	37.5	41.7	33.4	42.8	39.9	42.3
Snout length (preorbital direct)	20.8	21.3	24.0	14.7	22.0	18.9	22.7
Snout to spiracle	26.0	26.3	29.5	20.2	27.2	23.7	27.3
Head (dorsal length)	27.3	28.0	31.3	22.3	29.2	26.1	28.9
Orbit diameter	3.6	3.4	3.7	3.5	4.4	3.3	3.8
Orbit and spiracle length	5.3	4.8	5.4	5.1	5.9	5.3	5.5
Spiracle length (main pore)	2.1	1.7	2.2	1.6	2.2	1.9	2.6
Distance between orbits	5.5	5.1	6.1	4.9	6.0	6.5	7.0
Distance between spiracles	7.0	7.0	7.5	6.6	7.5	7.1	8.1
Distance-snout to cloaca	59.3	59.0	62.7	54.7	61.9	55.7	62.3
Cloaca to D1	25.3	23.9	26.5	0.0	0.0	23.2	27.4
Cloaca to D2	31.8	29.4	32.3	0.0	0.0	29.0	35.0
Cloaca to caudal origin	37.8	34.8	38.6	0.0	0.0	33.5	40.5
Distance-cloaca to caudal-fin tip	41.2	37.7	42.3	37.8	44.6	37.1	45.6
Ventral snout length (pre upper jaw)	20.6	21.3	24.7	15.1	21.7	20.2	22.2
Prenasal length	18.1	18.5	21.2	13.6	19.7	17.6	19.5
Ventral head length (to fifth gill)	36.1	36.6	38.8	31.1	36.9	35.9	37.7
Mouth width	9.6	8.6	9.5	7.9	9.9	9.5	9.6
Distance between nostrils	9.3	8.9	9.7	8.5	10.1	10.1	10.2
Nasal curtain length	5.3	4.9	5.6	4.6	5.5	4.2	5.4
Nasal curtain (total width)	10.5	9.5	10.7	9.7	11.2	10.1	11.3
Nasal curtain (min. width)	7.3	6.8	7.7	6.5	7.9	6.8	8.2

TABLE 3 (continued).

	Z. maugeana			Z. nasuta		Z. chilensis	
	holotype	min	max	min	max	min	max
Nasal curtain (lobe width)	1.9	1.4	2.2	2.1	2.4	1.5	2.6
Width of first gill opening	1.7	1.5	2.0	1.3	1.7	1.5	1.8
Width of fifth gill opening	1.6	1.4	1.7	1.2	1.4	1.3	1.8
Distance between first gill openings	16.1	15.6	17.1	14.5	17.3	16.9	19.6
Distance between fifth gill openings	9.1	8.9	11.1	8.3	11.5	10.7	11.0
Clasper (post cloacal length)	26.8	23.9	23.9	0.0	29.5	0.0	26.8
Length of anterior pelvic lobe	13.2	11.5	12.9	12.2	14.4	13.6	14.6
Length of posterior pelvic lobe	20.3	13.9	18.6	16.1	23.2	16.5	18.7
Pelvic base width	9.1	8.6	10.3	7.9	10.4	10.0	10.2
Tail at axil pelvic fins (width)	4.2	3.6	4.4	4.4	5.8	3.8	4.9
Tail at axil pelvic fins (height)	2.6	2.6	2.9	2.3	2.9	2.4	2.7
Tail at midlength (width)	3.2	2.7	3.0	2.9	3.9	2.4	3.1
Tail at midlength (height)	1.4	1.3	1.4	1.5	1.8	1.4	1.6
Tail at D1 origin (width)	2.7	2.5	2.7	2.2	3.2	2.2	2.7
Tail at D1 origin (height)	1.3	1.3	1.3	1.3	1.6	1.3	1.5
D1 base length	5.1	4.6	5.5	4.5	6.1	4.6	5.9
D1 height	3.5	2.8	3.8	2.7	3.9	2.8	3.2
D1 orig to caudal-fin tip	15.9	13.0	17.1	12.9	16.9	13.1	18.2
D2 orig to caudal-fin tip	9.3	7.4	10.0	6.8	10.2	7.7	10.4
Caudal-fin length	3.4	2.2	3.7	2.3	4.2	2.9	4.6

Remarks

The three *Zearaja* species can be distinguished based on size, morphometrics and squamation. *Zearaja maugeana* is physically smaller than both *Z. nasuta* and *Z. chilensis* and has a smaller size at maturity. The three adult male types of *Z. maugeana* were mature at 659–706 mm TL and females attain 840 mm TL. Age and growth in *Z. chilensis* has been comprehensively investigated and reviewed (Licandeo *et al.* 2006; Licandeo *et al. in press*). *Zearaja chilensis* exhibits geographic variation in size, but the onset of maturity varies from 750–850 mm TL in males (Licandeo *et al. in press*), with the largest recorded female 1680 mm TL (Lloris & Rucabado 1991). *Zearaja nasuta* is reported to occasionally reach 1000 mm TL (Ayling & Cox 1982), and 1084 mm TL based on museum specimens (NMNZ P 4783, not viewed).

Zearaja maugeana differs from *Z. nasuta* in the following morphometrics. Apart from attaining a smaller maximum size, *Z. maugeana* has a longer pre upper jaw length (20.6–24.7 vs. 15.1–21.7% TL), prenasal length (18.1–21.2 vs. 13.6–19.7% TL) and ventral head length (36.1–38.8 vs. 31.1–36.9% TL), shorter adult clasper (23.9–26.8 vs. 25.9–29.5% TL), and a less robust tail (width at axil of pelvic fin 3.6–4.4 vs. 4.4–5.8% TL; at midlength width 2.7–3.2 vs. 2.9–3.9% TL, height 1.3–1.4 vs. 1.5–1.8% TL). Its disc is proportionally narrower (width 1.09–1.12 times length) than either *Z. nasuta* (1.12–1.22 times) or *Z. chilensis* (1.19–1.29 times), and its snout to interorbit ratio (3.75–4.38 vs. 2.89–3.85 in *Z. nasuta* and 2.92–3.27 in *Z. chilensis*) and pre upper jaw to internasal ratio (2.20–2.58 vs. 1.66–2.26 in *Z. nasuta* and 1.98–2.20 in *Z. chilensis*) reflect its relatively narrow head and long snout. In addition, *Z. maugeana* differs markedly from *Z. chilensis* in disc width (66.5–70.5 vs. 73.9–76.9% TL), has a more evenly tapered tail (width at axil of pelvic fin 1.30–1.53 vs.

1.57–1.59 times width at midlength, 1.34–1.72 vs. 1.72–1.82 times width at first dorsal-fin origin), and a higher orbit to interorbit ratio (0.58–0.69 vs. 0.48–0.55). Males available to us of *Z. chilensis* were immature but based on Leible (1987), *Z. chilensis* attains an even larger size than its congeners and appears to have relatively large claspers as an adult. Leible examined male specimens exceeding 1050 mm TL and their claspers varied from 27–32% TL.

Zearaja nasuta, known as the rough skate (Ayling & Cox 1982), has a well-developed covering of fine denticles over its dorsal surface. In comparison, the dorsal surface of the pectoral fins of *Zearaja maugeana* is largely naked. There are also minor differences between the *Zearaja* species in the clasper configuration but their mode of operation is presumably identical. Differences relate primarily to the strength of various cartilages and to the position of the rhipidion. In *Z. maugeana* and *Z. nasuta*, the rhipidion is slender, rather than wavy, and is dispersed centrally along the dorsal margin of the ventral terminal cartilage, well away from lateral margin of the glans. The wavy rhipidion of *Z. chilensis* lies submarginal to the sharp edge of the shield.

Zoogeography

The genus *Zearaja* is a small group of skates whose ancestral form probably occurred on the continental shelves of Gondwana in the late Mesozoic (Last & Yearsley 2002). Continental drift and subsequent isolation of mainland Australia, New Zealand and South America within the last 80 my, has resulted in speciation leading to the existence of endemic extant skates in each region. The absence of the group in Antarctica could be due to Oligocene cooling, coinciding with a major loss in biodiversity of the Paleogene ichthyofauna (Long 1994). *Zearaja* are primarily inshore skates, unlike *Bathyraja* and *Dipturus* which are more diverse on deep continental slopes, and thus less affected by paleoclimatic upheavals. The extant distribution of *Zearaja* is congruent with a vicariance-based hypothesis rather than a cross-ocean dispersal based origin. Skates are very poor cross ocean dispersers (Springer 1982) and appear to move within narrow bathymetric pathways along continental shelves and slopes. *Zearaja maugeana* was presumably more widely distributed in southern Australian seas but it is unclear whether its present relic distribution is a product of past climate change, a reduction in habitat availability, interspecific competition, a change in habitat preference, or a combination of these factors. Intermittent oceanic warming and cooling in the Pleistocene is thought to be responsible for the derivation of much Australia's recent temperate marine biota. It is also thought to have created extinctions. The benthic habitats of Port Davey are unique within Australia, with the substrate more typical of the silts and terrigenous oozes found on the continental slope. Deepwater species of *Dipturus* and *Zearaja* usually have a long snout and this condition could be an adaptation to feeding on the infauna of very soft substrates.

Knowledge of evolutionary history *Zearaja* may be important in understanding the origin of skates. If the group is ancestral to other rajins, then the accessory terminal 2 cartilage probably preceded the accessory terminal 1 cartilage as a skeletal element in skates. Conversely if the group is advanced, it is likely that the accessory terminal 1 cartilage has been lost. Hulley (1972) noted that only one accessory terminal component is present in *Rhinobatos,* a presumed ancestral group of skates. This state is also present in *Zearaja* but species of *Dipturus* have two accessory terminal cartilages. The most likely scenario, based on a Gondwanan lineage of *Zearaja*, is that the accessory terminal 2 is plesiomorphic and the presence of an accessory terminal 1 cartilage is more derived. *Dipturus* is probably the more advanced of the two genera. A molecular study (Holmes pers. comm.), based on sequences of the CO1 gene, supports the hypothesis that *Zearaja* is ancestral to *Dipturus* but confirmation from other morphological and genetic analysis is needed.

Acknowledgements

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