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Narcine lasti, a new species of numbfish from Western Australia and Indonesia (Chondrichthyes: Torpediniformes: Narcinidae)

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Abstract – *Narcine lasti*, n. sp., is described from abundant material mostly collected from the Western Australian coast. The new species is distributed from Green Head and the Houtman Abrolhos in the eastern Indian Ocean to southeastern Indonesia in the Arafura Sea, along the upper continental slope. *Narcine lasti* is distinguished by a unique combination of characters including a tail length much longer than disc width or length, uniform yellowish-brown to yellowish-pink dorsal colouration that also extends anteriorly over preorbital snout region, lateral tail folds low and ridge-like, disc width and length with means of 40.3 and 42.1 % of total length (TL) respectively, nasal curtain much wider than long, and preorbital snout length over 10 % of TL. *Narcine lasti* is most similar to *N. tasmaniensis* and another undescribed species of *Narcine* from off the Queensland coast of Australia. All three species have relatively similar proportions and dorsal colouration, but can be distinguished on the basis of preorbital snout length, disc width and length, lateral tail fold morphology and usually also in dorsal colouration. *Narcine lasti* is easily distinguished from *Narcine westraliensis* McKay, 1966, the only other species of the genus in Western Australia, by many features including disc shape, relative proportions of the tooth bands, and in dorsal colouration. Both species do not co-occur, as *N. westraliensis* is distributed on the continental shelf in relatively shallow waters, while *N. lasti* is confined to deeper waters of the continental slope.

INTRODUCTION

The chondrichthyan fauna of Australia is one of the most diverse in the world with as many as 300 species, an estimated one-third of which is still undescribed (Last and Stevens, 1994; Last and Séret, 1999). Systematic studies of Australian chondrichthyans have progressed at a relatively slow pace since G. P. Whitley's classic review (Whitley, 1940). This situation was dramatically changed by the publication of "Sharks and Rays of Australia" by Last and Stevens (1994), with descriptions and much information concerning all Australian chondrichthyans, accompanied by excellent colour illustrations of all species. Last and Stevens (1994) reported five species of the torpediniform genus *Narcine* Henle, 1834 from Australia, three of which were treated as undescribed.

In conducting revisionary studies of electric ray genera, the senior author examined numerous specimens of an undescribed species of *Narcine* present off the coast of Western Australia (Carvalho, 1999a). Specimens of this undescribed form were first collected in 1978, but due to extensive sampling mostly on the R/Vs Soela, Southern Surveyor and Invincible in the 1980s and early 1990s, abundant material is now available in Australian collections. Additional specimens of this new species were collected by the junior author from two proximal localities in 1991 during the exploratory cruise "Karubar," trawling off southeastern Indonesia. We describe below this new species, which corresponds to "*Narcine* sp. B" of Last and Stevens (1994) and "*Narcine* sp. nov. B" of Carvalho (1999a).

Electric rays of the genus *Narcine* ("numbfishes" or "lesser electric rays") are usually small to medium-sized batoids, occurring in tropical to subtemperate waters in most major oceans (Bigelow and Schroeder, 1953). They are conspicuously absent from the Mediterranean and Red seas, the west African coast, New Zealand, Pacific Plate islands, and regions predominantly influenced by cold water currents. They are more common on continental shelf or upper slope areas, and are believed to have a relatively low mobility (e.g.

Rudloe, 1989). *Narcine* is distinguished from the other nine valid electric ray genera by a unique combination of characters, including two dorsal fins, a prominent circumoral groove, stout labial cartilages, expanded trough-shaped rostrum, branching antorbital cartilages, tooth bands extending onto the external oral integument, functional eyes, and posteriorly separated pelvic fins (Bigelow and Schroeder, 1953; Compagno, 1973; Carvalho, 1999a). Carvalho (1999a) revised the genus, recognising 20 valid species, nine of which were undescribed. The species description presented here is done in advance of the forthcoming publication of the generic revision by the senior author.

MATERIALS AND METHODS

Comparative material of all species of *Narcine* was used for the present description, and is listed in Carvalho (1999a). Non-type material of the new species is listed at the end of this paper. Institutional abbreviations follow Leviton *et al.* (1985). Measurements were taken in a straight line, from point to point, using electronic callipers to the nearest tenth of a millimetre, following the methods established in Carvalho (1999a) for narcinid electric rays. Specimens greater than 150 mm were measured with steel ruler or with a tape measure, and are expressed to the nearest millimetre. Measurements were conducted on specimens in order to obtain proportional morphometric characters useful for descriptive and identification purposes, but certain caution is warranted when specimens appear damaged, dehydrated or distorted from their original state, which may be common with electric rays (Fechhelm and McEachran, 1984; Carvalho, 1999b). All measurements are presented in Table 1, and are expressed as proportions of total length in order to be readily available for comparisons. Measurements are as follows: total length (TL, in millimetres; independent variable from which all proportional values are derived); disc width (DW, across widest aspect of disc, usually close to level of third gill openings); disc length (DL, from anterior snout region to greatest disc length, lateral to pectoral axil); preorbital snout length (PBS, from in between anterior level of eyes to anterior margin of snout); preoral snout length (POS, from top of lower tooth band to anterior margin of snout); prenasal snout length (PNS, from in between anterior level of nostrils to anterior snout margin); snout to greatest disc width (SDW, from anterior snout to level of greatest disc width, measured over mid-disc); interorbital distance (IOD, straight distance between inner margins of orbits); eye length (EL, between anterior and posterior margins of eye); interspiracular distance (ISD, between inner margins of spiracles); spiracle length (SPL, greatest anteroposterior distance through spiracle); spiracle width (SPW, greatest lateral extent of spiracle); mouth width (MW, distance between mouth corners, measured between junction of upper and lower labial cartilages of each side of jaws); upper tooth band width (UTB, width of exposed upper tooth band in between posterior margin of lips [formed by the upper labial cartilages], close to mouth opening); lower tooth band width (LTB, width of exposed lower tooth band at anterior margin of lips [formed by the lower labial cartilages], close to mouth opening); nasal curtain width (NCW, width of nasal curtain at greatest width below nostrils); nasal curtain length (NCL, length of nasal curtain from level of anterior margin of nostrils to posterior-most point at mid-line of nasal curtain); distance between nostrils (DBN, between inner margins of nostrils); distance between first gill openings (FGO, between inner margins of first pair of gill openings); distance between last gill openings (LGO, between inner margins of last pair of gill openings); branchial basket length (BBL, between first and last gill openings); pelvic fin length (PFL, length of pelvic fin from insertion to posterior-most point, measured ventrally); pelvic fin width (PFW, distance between outer-most corners of pelvic fins, from tip to tip, measured ventrally); anterior margin of pelvic fin (AMP, greatest extent from insertion to outer-most corner of pelvic fin); posterior margin of pelvic fin (PMP, greatest extent from outer-most corner to posterior-most point of pelvic fin); tail width (TW, extent across base of tail at greatest width, measured dorsally); height of first dorsal fin (HFD, distance from greatest height at apex to mid-base of first dorsal fin); length of first dorsal fin (LFD, greatest length of base of first dorsal fin); height of second dorsal fin (HSD, distance from greatest height at apex to mid-base of second dorsal fin); length of second dorsal fin (LSD, greatest length of base of second dorsal fin); length of dorsal lobe of caudal fin (LDC, distance from origin on dorsal caudal peduncle to posterior-most tip of caudal fin); length of ventral lobe of caudal fin (LVC, distance from origin on ventral caudal peduncle to posterior-most tip of caudal fin); height of dorsal lobe of caudal fin (HDC, measured vertically from upper-most tip of caudal fin apex to base of dorsal lobe on tail); height of ventral lobe of caudal fin (HVC, measured vertically from lower-most tip of caudal fin to base of ventral lobe on tail); height of caudal fin (HC, greatest distance between dorsal and caudal fin margins, does not equal HDC + HVC); distance between dorsal fins (DBD, distance between posterior tip of first dorsal fin base and anterior tip of second dorsal fin base); distance between second dorsal fin and caudal fin (SDC, from posterior tip of second dorsal fin to dorsal origin of caudal peduncle); distance between

snout and cloaca (SCL, between anterior snout margin to origin of cloaca); distance between cloaca and caudal fin (CLC, from posterior tip of cloaca to posterior margin of caudal fin, equals tail length); distance between snout and first dorsal fin (SFD, from anterior margin of snout to origin of first dorsal fin); electric organ length (EOL, from anterior margin to posterior margin of electric organ, measured ventrally); electric organ width (EOW, greatest width of electric organ at its mid-length, close to level of third gill slit, measured ventrally); clasper length (CL, from posterior tip of cloaca to distal-most tip of clasper).

Meristic features were extracted from radiographs following Carvalho (1999a) and are presented in Table 2. Meristic characters are as follows: propterygium radials (PRO); mesopterygium radials (MES); metapterygium radials (MET); total pectoral radials (TPR = PRO + MES + MET); pelvic radials (PVR); first dorsal fin radials (FDR); second dorsal fin radials (SDR); dorsal lobe of caudal fin radials (DCR); ventral lobe of caudal fin radials (VCR, includes radial situated in between dorsal and ventral aspects of caudal fin); total caudal radials (TCR = DCR + VCR); exposed vertical tooth rows on upper tooth band (UTR, corresponds to tooth rows visible externally on upper jaw when mouth is closed); exposed vertical tooth rows on lower tooth band (LTR, corresponds to tooth rows visible externally on lower jaw when mouth is closed); trunk vertebral centra (TC, from first whole distinguishable centrum in synarcual to anterior margin of pelvic girdle, further explained below); precaudal vertebral centra (PC, centra from anterior margin of pelvic girdle to upper origin of caudal fin); caudal vertebral centra (CC, from first centrum in caudal fin to last distinguishable centrum); total vertebral centra (TV = TC + PC + CC); ribs (R, relatively elongated pleural ribs articulating with paired haemal spines, located posteriorly on disc slightly dorsal to pelvic girdle area). Interpreting monospondylous to diplospondylous transitions from radiographs was not always possible, and therefore the division of the vertebral column into trunk and precaudal centra is based on the pelvic girdle (we fully realise that this may prove to be slightly variable in other batoids such as skates, but this was not the case in *Narcine*). Radial elements of the pectoral and dorsal fins that are joined at base but radiate outward in a bifidly were counted as two separate elements. Tooth counts were taken under stereomicroscope and follow the method presented in Stehmann (1978), where individual tooth rows (more appropriately designated as "files") are counted following a cranial-caudal orientation. Only exposed tooth rows were counted, i.e. rows visible on tooth bands when the mouth is closed (dissection is necessary to count internal tooth rows because of the strong labial cartilages immediately lateral to the tooth bands, and dissection is not always possible). Tooth counts are expressed as fractions, where the numerator designates the number of exposed rows on the upper jaws, and the denominator indicates the same on the lower jaws (e.g. 16/14, 16/14–18/17).

The description of the skeleton is not meant to be exhaustive and is restricted to features that can be observed in dorso-ventral view (taken from radiographs). Terminology for anatomical elements follows Carvalho (1999a).

SYSTEMATICS

Order Torpediniformes Berg, 1940

Family Narcinidae Gill, 1862

Narcine Henle, 1834

Diagnosis

Narcinid electric rays distinguished from the other three genera of the family (*Discopyge* Heckel, 1846, *Benthobatis* Alcock, 1898 and *Diplobatis* Bigelow and Schroeder, 1948) by the following unique combination of external features: joint nasal curtain with straight posterior margin, without median posterior flap (present in *Discopyge*); pelvic fins separated posteriorly, not joined to form "apron" (present in *Discopyge*); eyes functional and clearly visible externally anterior to spiracles, usually about same size or slightly larger or smaller than spiracles (eyes externally not readily visible in *Benthobatis*); nostrils are a single opening, not subdivided into two distinct compartments by bridge of stiff integument between dorsal nasal curtain and ventral nasal flaps (nostrils fully divided in *Diplobatis*); claspers adjoined latero-externally to pelvic fins, not covered and concealed dorsally by pelvic fins (condition in *Diplobatis* and some species of *Benthobatis*); both lower and upper tooth bands remain exposed on external oral integument when mouth is closed (tooth bands not readily exposed in *Diplobatis* and *Benthobatis*); lateral tail folds or ridges on lateral aspect of tail generally well developed, extending from level of first dorsal fin posteriorly to caudal peduncle (*Benthobatis* has rudimentary lateral tail ridges). The following anatomical features are hypothesised as supporting the monophyly of *Narcine* (Carvalho, 1999a): fused and paired hypobranchial plates with sinuous external margins, articulating with ceratobranchials 2–4; facio-palatine foramen present within the orbit; conspicuous heart-shape of basibranchial copula that bears a well-developed, slender posterior process; lack of contact between ceratohyal and the component tentatively identified as being the first hypobranchial.

Narcine lasti, new species
Figures 1–7, Tables 1–2

Narcine sp. 1: Gloerfelt-Tarp and Kailola, 1984: 36 (brief description).

Narcine sp.: Sainsbury *et al.*, 1985: 44, 330 (brief comparison, listed).

Narcine sp. B: Last and Stevens, 1994: 376, plate 66, figure 39.2 (identification, description, distribution, illustrated in colour); Williams *et al.*, 1996: 144 (listed); Carvalho *et al.*, 2000: 1441 (identification, distribution, illustrated).

Narcine sp. nov. B: Carvalho, 1999a: 219–226, figures 77–81 (diagnosis, description, distribution, illustrated, colour photographs).

Holotype

CSIRO H1036-03, 325 mm TL adult female, from north of Cape Lambert (Western Australia [WA]) at 19°06'S, 117°08'E, 178–183 m, FRV Soela, S07-87-129, 12 October 1987. Figure 1.

Paratypes

21 specimens total (115–365 mm TL)–AMS I 31174-010, 234 mm TL pre-adult male (almost adult), off Shark Bay (WA), 26°42.3'S, 112°38.4'E–26°42.1'S, 112°38.5'E, 285 m, FRV Southern Surveyor, 30. January 1991; CSIRO H1035-01, 331 mm TL adult female, from north of Dampier archipelago (WA), 19°08'S, 116°54'E, 196–198 m, FRV Soela, S06-86-84, 24 October 1986, CSIRO H1035-02, 330 mm TL adult female (data as in H1035-01); CSIRO H1035-03, 272 mm TL adult male (data as in H1035-01); CSIRO H1036-01, 325 mm TL adult female (data as in holotype); CSIRO H1036-02, 312 mm TL pre-adult or adult female (data as in holotype); CSIRO H2597-08, 365 mm TL adult female (Figure 2), from west of Green Head (WA),

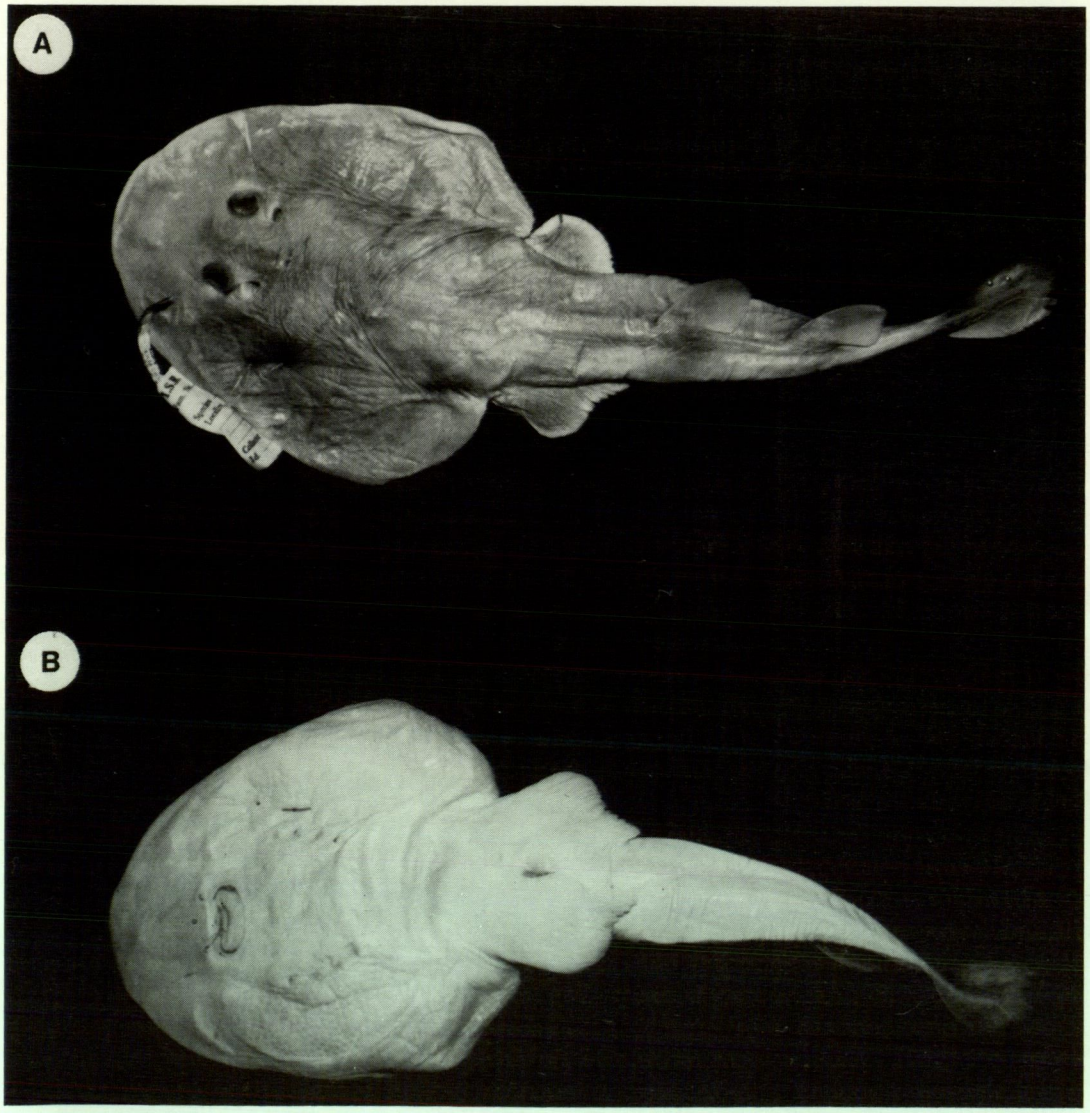

Figure 1 Dorsal (A) and ventral (B) views of holotype of *Narcine lasti*, n. sp., (CSIRO H1036-03, 325 mm TL adult female); from north of Cape Lambert, WA, 19°06'S, 117°08'E, 178–183 m.

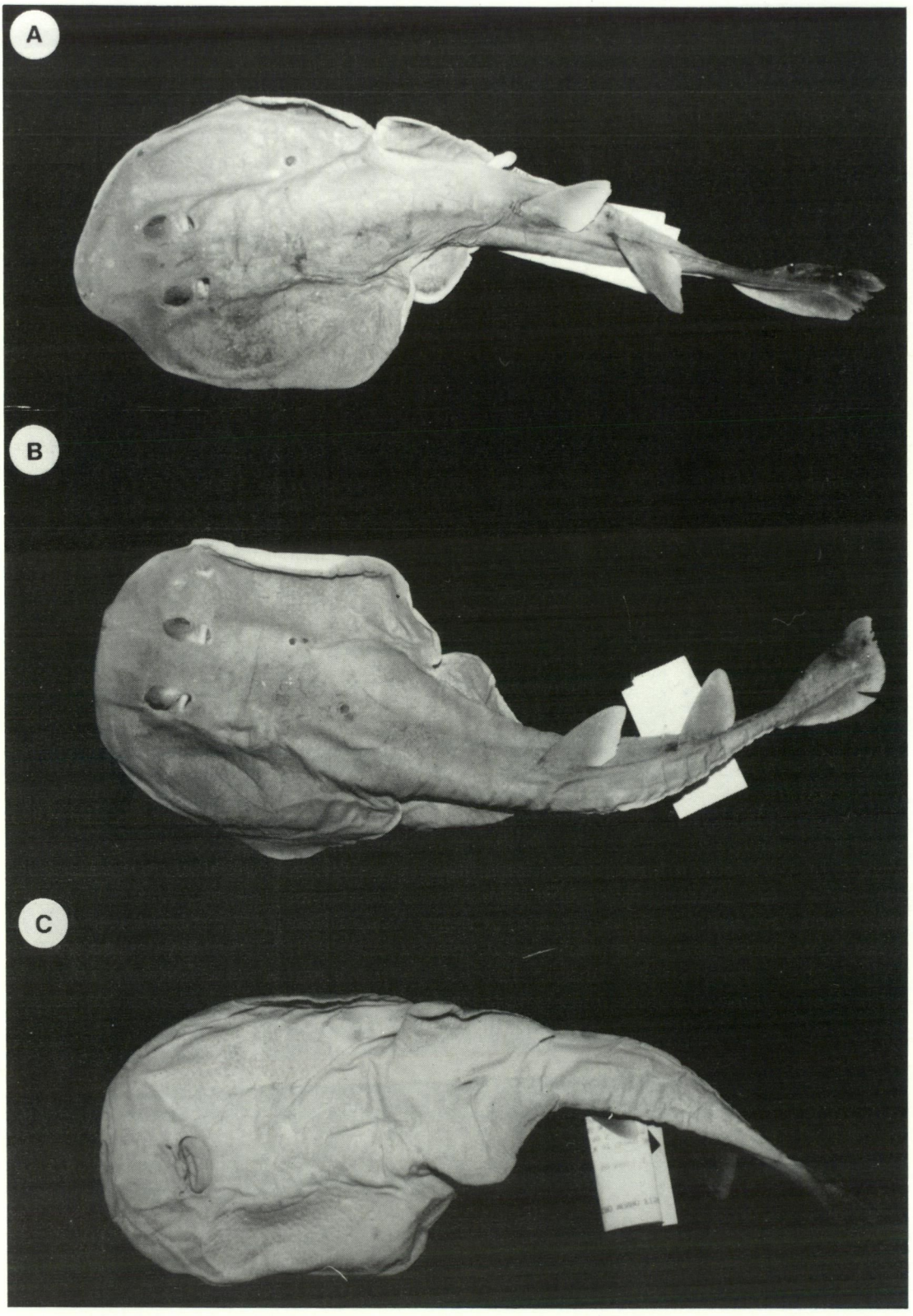

Figure 2 Paratypes of *Narcine lasti*, n. sp.: A) dorsal view of CSIRO H2597-09 (mature male, 302 mm TL); B) and C) dorsal and ventral views respectively of CSIRO H2597-08 (adult female, 365 mm TL); both specimens from west of Green Head (WA), 29°59'S, 114°28'E, 265 m.

29°59'S, 114°28'E, 265 m, FRV Southern Surveyor, SS 0191/63, 8 February 1991; CSIRO H2597-09, 302 mm TL adult male (Figure 2) (data as in H2597-08); CSIRO H3222-06, 315 mm TL adult female, north of Dampier archipelago (WA), 19°12'S, 116°25'N, 190 m, FRV Southern Surveyor, SS 2/90/136, 11 October 1990; CSIRO H4070-06, 256 mm TL pre-adult male, from northwest of Port Hedland (WA),

Figure 3 Dorsal (A) and ventral (B) view of paratype of *Narcine lasti*, n. sp., MNHN 1996-1556 (302 mm TL adult female from the Arafura Sea, off Tanimbar Island, Indonesia, 9°01'S, 132°42'E, 246–253 m).

18°12'S, 118°14'E, 269 m, FRV Southern Surveyor, SS 8/95/123; CSRIO H4070-07, 244 mm TL pre-adult female (data as in H4070-06); CSRIO H4070-08, 250 mm TL pre-adult male (data as in H4070-06); MNHN 1996-1556 (3 specimens), 302 mm TL adult female (Figure 3), 190 mm TL juvenile male, 115 mm TL juvenile male, from off Tanimbar Island (Indonesia), 9°01'S, 132°42'E, 246–253 m, cruise "Karubar," sta. CP62, 1 November 1991; NMV A1798 (2 specimens), 305 mm TL adult female, 270

mm TL adult male, southwest of Shark Bay (WA), 27°07'S, 112°49'E–27°01'S,112°48'E, 238–248 m, R/V Hai Kong, 3 March 1981; WAM P26208-025 (4 specimens), 261 mm TL adult male, 241 mm TL pre-adult, 232 mm TL pre-adult male, 231 mm TL pre-adult male, 225 km NNW of Port Hedland (WA), 18°22'S, 118°03'E, 258–270 m, R/V Courageous (J. Barry Hutchins), shot 0693, 20 May 1978.

Diagnosis

A species of *Narcine* from the eastern Indian Ocean and Arafura Sea diagnosed by the following unique combination of characters: tail length as measured from cloaca much longer than disc width or length (tail length with a mean of 53.7 % of TL, compared to means of 40.3 % of TL for disc width and 42.1 % of TL for disc length); nasal curtain much wider than long; uniform light yellowish-brown dorsal colour pattern, which is also present over preorbital snout region, and without any distinctive spotting or other markings over disc and tail; low and inconspicuous lateral tail ridge, not resembling a distinct fold; mean preorbital snout length just over 10 % of TL.

Table 1 Measurements for *Narcine lasti*, n. sp. N is number of specimens from which means and standard deviations (SD) were taken, and includes type and non-type specimens. Holotype: CSIRO H1036-03. Paratypes (excludes 2 specimens from MNHN 1996-1556, 190 and 115 mm TL juvenile males, and all four WAM P26208-025 specimens): AMS I 31174-010, CSIRO H1035-01, H1035-02, H1035-03, H1036-01, H1036-02, H2597-08, H2597-09, H3222-06, H4070-06, H4070-07, H4070-08, MNHN 1996-1556 (302 mm TL female), NMV A1798 (2). See material and methods section for explanation of acronyms.

	HOLOTYPE	PARATYPES	NON-TYPES	N	MEAN	SD
TL (mm)	325.0	234.0–365.0	144.0–361.0	53	—	—
DW (%)	43.4	38.5–43.7	34.1–45.2	53	40.3	2.1
DL (%)	44.0	40.4–44.4	38.2–48.6	53	42.1	1.9
PBS (%)	10.6	8.7–11.1	8.5–12.6	53	10.1	0.8
POS (%)	13.9	12.1–14.4	11.4–15.7	53	13.4	0.9
PNS (%)	10.9	8.5–10.4	8.4–12.0	53	9.8	0.7
SDW (%)	32.3	29.5–34.0	29.1–35.6	53	32.1	1.7
IOD (%)	5.3	5.0–6.9	4.4–6.7	53	5.7	0.5
EL (%)	3.0	2.8–3.6	2.6–4.5	53	3.3	0.4
ISD (%)	6.2	5.4–6.7	4.5–7.0	53	6.0	0.5
SPL (%)	2.1	1.9–2.8	1.6–3.0	53	2.2	0.3
SPW (%)	2.3	1.8–2.7	1.7–3.6	53	2.4	0.3
MW (%)	6.3	5.9–7.5	5.3–7.0	53	6.3	0.4
UTB (%)	2.4	1.8–2.6	1.4–2.9	53	2.1	0.3
LTB (%)	1.5	1.0–2.1	1.0–2.3	52	1.6	0.3
NCW (%)	5.0	4.7–6.5	4.1–6.4	52	5.3	0.5
NCL (%)	2.5	1.7–5.0	1.9–3.2	46	2.4	0.6
DBN (%)	4.4	3.2–6.2	4.4–5.9	53	5.1	0.5
FGO (%)	14.2	11.5–14.3	10.2–14.5	53	12.7	0.9
LGO (%)	10.2	7.3–10.5	6.1–10.1	53	8.5	1.0
BBL (%)	7.4	7.7–9.6	6.4–9.9	53	8.5	1.0
PFL (%)	17.2	13.8–18.9	12.3–18.4	53	15.7	1.7
PFW (%)	23.1	18.4–29.2	19.6–28.9	53	25.2	2.1
ALP (%)	8.0	6.4–10.4	6.2–12.2	52	8.8	1.3
PLP (%)	14.5	9.9–17.4	7.9–18.8	52	12.8	2.4
TW (%)	17.2	15.1–19.7	10.8–19.4	53	16.5	1.9
HFD (%)	8.7	7.9–10.3	5.9–10.6	53	8.6	1.0
LFD (%)	6.0	5.3–6.6	5.2–6.9	53	5.8	0.4
HSD (%)	8.3	8.2–10.4	7.0–10.4	53	8.6	0.9
LSD (%)	5.7	6.0–6.8	4.9–7.5	53	6.3	0.5
LDC (%)	12.6	12.1–16.4	11.5–16.7	53	13.3	1.1
LVC (%)	13.4	12.5–16.4	11.5–17.2	53	14.3	1.1
HDC (%)	3.5	2.9–4.6	2.5–4.3	53	3.6	0.4
HVC (%)	3.4	2.2–4.5	2.6–4.3	53	3.5	0.5
HC (%)	9.9	7.4–10.0	6.4–9.8	53	8.2	0.9
DBD (%)	7.3	6.4–9.3	4.0–9.9	53	7.7	0.9
SDC (%)	8.8	7.1–9.4	7.6–11.3	53	9.1	0.9
SCL (%)	44.6	40.0–45.6	37.9–47.6	53	42.5	1.8
CLC (%)	52.6	51.7–57.1	50.0–56.6	53	53.7	1.6
SFD (%)	58.1	54.0–57.8	50.3–59.0	53	55.3	1.6
EOL (%)	23.7	18.4–21.9	16.7–24.0	53	20.1	1.5
EOW (%)	7.4	5.5–8.9	5.0–9.4	53	7.5	1.0
CL (%)	–	12.4–12.9	7.2–13.9	19	11.4	2.1

Table 2 Counts for *Narcine lasti*, n. sp. A) CSIRO H1036-01 (paratype); B) CSIRO H2597-09 (paratype); C) MNHN 1996-1556 (paratype); D) NMV A9656; E) NTM 13579-004; F) NTM 12641-021; G) CSIRO 4367; H) NMV A1798 (paratype); I) NMV A1798 (paratype); J) NTM 13578-009. Dashes represent counts not available in radiographs. See material and methods section for explanation of acronyms.

	A	B	C	D	E	F	G	H	I	J	RANGE
TL (mm)	325	302	302	254	250	297	261	305	270	311	250 - 325
PRO	15	18	14	16	16	15	14	16	16	16	14–18
MES	6	5	6	5	6	6	6	6	6	6	5–6
MET	8	10	9	9	7	8	9	9	7	8	7–10
TPR	29	33	29	30	29	29	29	31	29	30	29–33
PVR	19	18	17	18	19	17	17	19	18	17	17–19
FDR	9	—	9	7	8	10	—	—	7	—	7–10
SDR	—	9	9	—	9	10	9	—	8	—	8–10
DCR	27	24	26	26	25	26	29	27	25	24	24–29
VCR	31	27	29	29	27	29	30	30	29	26	26–31
TCR	58	51	55	55	52	55	59	57	54	50	50–59
TC	17	16	17	17	16	17	17	16	16	16	16–17
PC	71	76	73	71	72	71	71	71	72	71	71–76
CC	30	27	27	28	27	29	31	26	26	25	25–31
TV	118	119	117	116	115	117	119	113	114	112	112–119
R	7	6	7	6	5	6	6	6	6	6	5–7

Description

Measurements and counts are summarised in Tables 1 and 2, respectively.

External morphology – Disc slightly oval in some specimens, generally longer than wide (disc length is 38.2 to 48.6 % of TL, disc width is 34.1 to 45.2 % of TL), and distinctively shovel-shaped in most preserved specimens. Disc widest relatively posteriorly close to pectoral fin insertion, at posterior one-fourth or one-fifth of its length in adults, and at around one-sixth in juveniles. Disc just barely overlaps origin of pelvic fins at its posterior aspect, and does not leave a prominent free lobe posteriorly. Snout rounded but may be slightly angled in some preserved specimens. Preorbital snout length about one-tenth of total length, and about one-third of disc length. Electric organs not clearly visible dorsally, more conspicuous in juveniles. Electric organs originate just anterior to level of eyes dorsally and continue posteriorly to about five-sixths of disc length; ventrally electric organs originate just posterior to level of nostrils. Electric organ length between 16.7 to 24.0 % of TL, and width between 5.0 and 9.4 % of TL. Gill slits semi-circular, small and positioned more or less in a straight line from first to last gill slit. Distance between last gill slits and branchial basket length about equal. Spiracles separated from eyes by a small gap in juveniles, but gap reduced in adults; spiracles without strongly elevated rims but with rounded posterior margins. Spiracle length and width about equal. Pseudobranchials folds present inside anterior

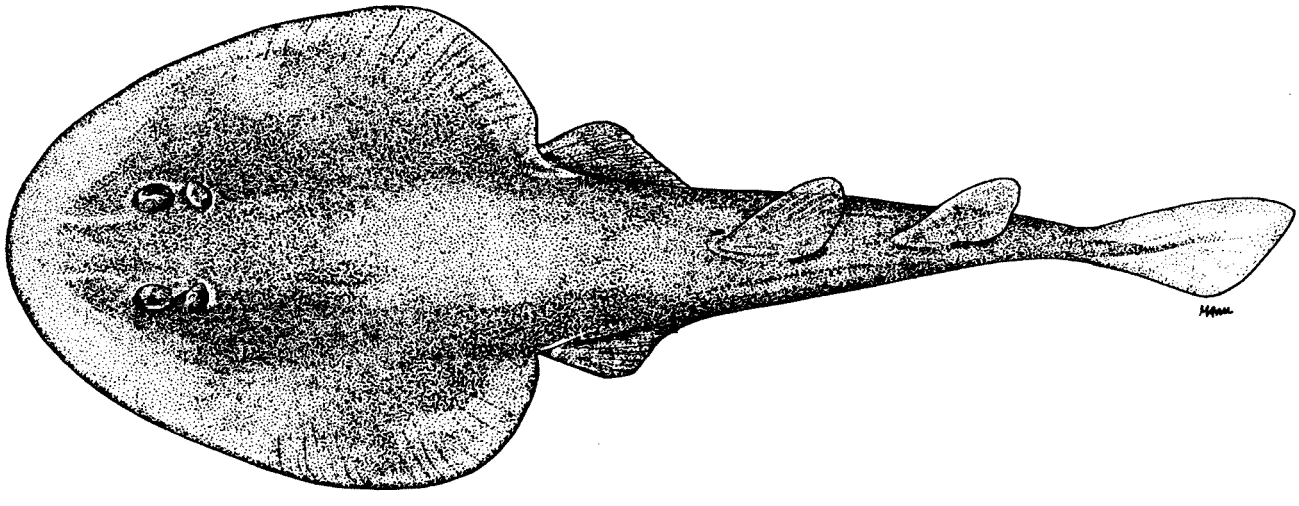

Figure 4 Illustration of *Narcine lasti*, n. sp., in dorsal perspective (from Carvalho *et al.*, 2000; used with permission from FAO).

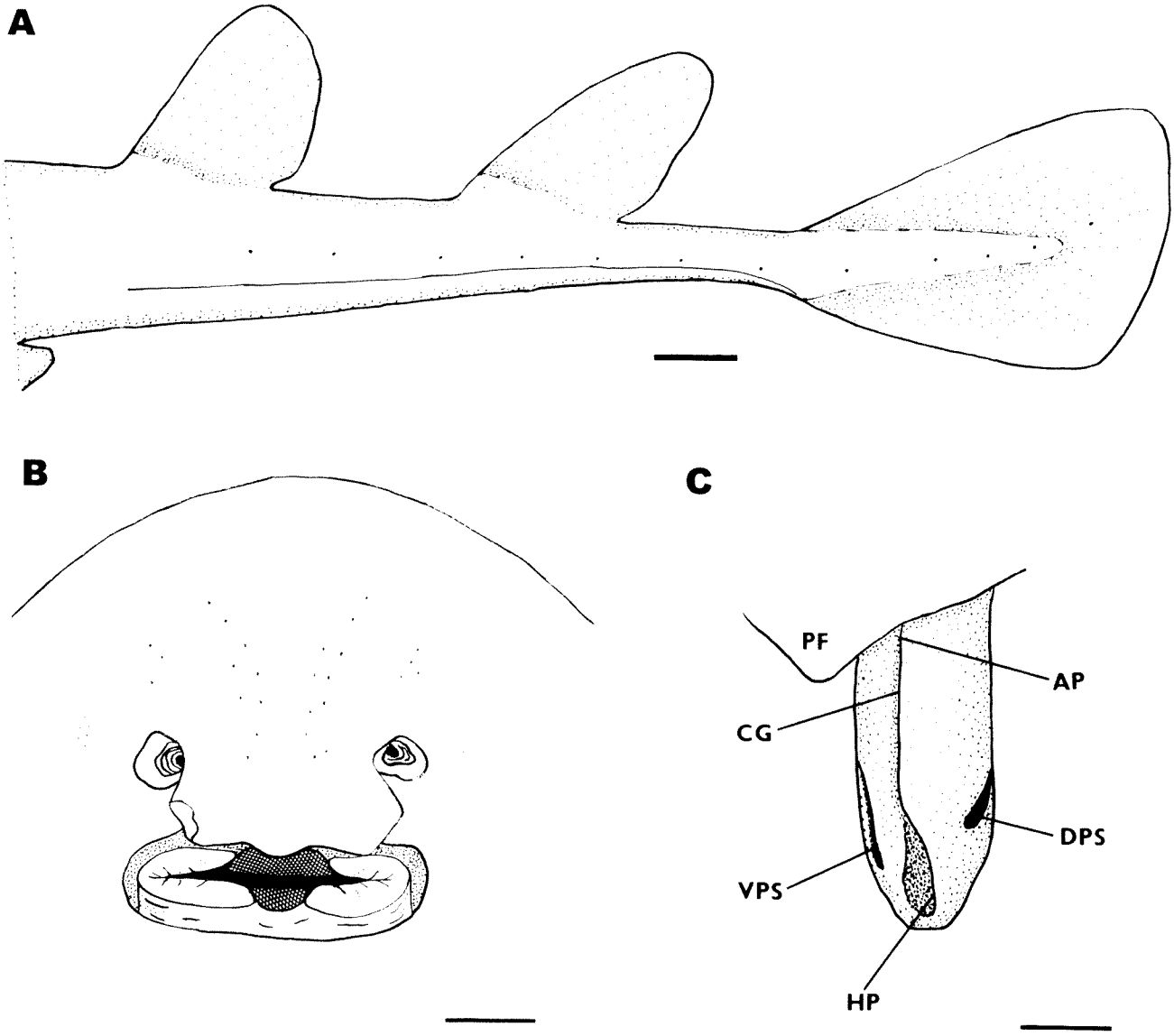

Figure 5 A) Lateral tail region of holotype (CSIRO H1036-03) of *Narcine lasti*, n. sp., showing distribution of lateral tail pores, lateral tail ridge, and relative positions of pelvic and dorsal fins; B) ventral snout region of holotype showing arrangement of external tooth bands and nasal curtain; C) external morphology of left clasper (compiled from various specimens). Abbreviations: AP, apopyle; CG, clasper groove; DPS, dorsal pseudosiphon; HP, hypopyle; PF, pelvic fin; VPS, ventral pseudosiphon. Scale bar = approximately 15 mm.

spiracular wall (eight within each spiracle in paratype MNHN 1996–1556; the same amount present in other specimens, e.g. MNHN 1996–1557). The individual pseudobranchial fold located farthest toward mid-line situated deeper within the spiracle. Eyes slightly bulging, longer than wide and longer than spiracles, and faintly darker than background disc colour.

Nasal curtain wider than long (Figure 5B), with straight posterior margin in most specimens, but a small central posterior lobe may be present in well-preserved material. Nasal curtain projects slightly laterally posterior to nostrils, giving it a faint trilobed appearance. Nostrils very circular with slightly elevated, wide rims. Prenasal snout length almost equal to preorbital snout length (in relation to total length, averaging close to 10 % of TL). Sensory pores on ventral snout region (Figure 5B) do not continue posteriorly to level of nostrils. Mouth generally only slightly wider than distance between outer nostrils. Upper tooth band wider than lower tooth band, fairly circular in outline. Lower tooth band may be more acute in outline appearing sub-triangular in some specimens. Teeth in 11/8–20/15 exposed vertical rows in pre-adults and adults (a typical adult of more than 300 mm in total length will have about 19/15 rows). Teeth in quincunx arrangement, with trapezoidal or diamond-shaped crowns, slightly wider than long. Cusps relatively long, especially on more inner rows, but more exposed teeth have cusps considerably more worn.

Pelvic fins when measured together wider than long, with longer posterior rather than anterior margins, and with a small free lobe posteriorly. Pelvics extend caudally from just underneath disc to just anterior to level of origin of first dorsal fin on tail. Pelvics somewhat rounded laterally, with fleshy lateral corners. In adult males, claspers relatively slender and elongated. Claspers in mature males project to about one-fifth of their total length beyond tips of pelvics, reaching close to one-half of first dorsal fin base length. Clasper groove inflects somewhat abruptly towards mid-line close to its mid-length between apopyle and hypopyle, and continues to terminate close to clasper distal tip (Figure 5C). Both dorsal and ventral pseudosiphons present, but ventral pseudosiphon relatively straight and clearly longer than dorsal pseudosiphon; dorsal pseudosiphon curved, wrapping slightly around internal margin of clasper. Tail long, ranging from 50.0 to 57.1 % of TL as measured from cloaca, but not very broad at base (mean is 16.5 % of TL). Tail sub-circular in cross section. Tail not tapering greatly from base to second dorsal fin, but tapering more from second dorsal to caudal fin. Lateral tail ridges not prominent, difficult to discern in some specimens, and appearing only as a low ridge (not a fold or flap). Lateral tail ridge beginning underneath level of first dorsal fin base, from origin to mid-base level in well-preserved specimens, inserting on lateral aspect of caudal peduncle close to its ventral margin (Figure 5A). First dorsal fin originates at a relatively posterior position on tail, generally behind apex of pelvic fins. Dorsal fins slightly rounded to sub-acute at apex, with sloping anterior and curved posterior margins. Dorsal fins insert on tail leaving a small free lobe posteriorly. Both dorsal fins very similar in size and shape, but second dorsal usually more slanted. Distance between second dorsal and caudal fin generally greater than distance between dorsal fins. Caudal fin low and moderately long (reaching to approximately 13 to 14 % of TL), with relatively straight posterior margin. Height of caudal fin, as measured with both upper and lower lobes together, about equal to height of dorsal fins. Lower lobe of caudal fin begins just anterior to level of origin of upper caudal fin lobe in some larger specimens.

As in all Australian species of *Narcine*, pores of the lateral-line and ampullary systems very difficult to observe and identify on both dorsal and ventral surfaces without more specific preparation. Few pores of the lateral canal present on the lateral tail region; these just dorsal to the lateral tail ridges (Figure 5A), continuing caudally beyond the level of caudal peduncle to terminate on the caudal fin tip at its mid-height. Very few scattered pores present of the hyomandibular and scapular canals outlining electric organs dorsally (ampullary pores outlining electric organs ventrally also present). Ampullary pores on ventral snout region in two relatively straight antero-posterior rows, with the last pores of each row somewhat laterally displaced (Figure 5B). Pores do not continue far posterior of level of anterior margins of nostrils. Two small group of pores anterior to each nostril on ventral snout area, and one pair of inconspicuous endolymphatic pores present posterior to eyes at mid-line.

Colouration – Dorsal colouration in preservative usually pale yellow to light tan or faded beige. Freshly caught specimens may be yellowish-pink over disc and tail (perhaps due to internal haemorrhaging). Specimens have a very uniform colour dorsally, with areas of slightly lighter intensity over pelvic fin margins, anterior region of pelvic fins, and at lateral tail base regions. Dorsal and caudal fins semi-transparent posteriorly. In preserved specimens, dorsal colouration may seem even lighter, but always a yellowish beige or tan. Ventrally specimens are a pale white to cream colour, devoid of more distinctive markings.

Skeletal anatomy – Skeleton calcified throughout, but superficial calcification particularly developed over neurocranium (especially at occipital condyles), synarcual, scapulocoracoid, pelvic girdle and pectoral fin-base. Neurocranium elongated, its length about one-half of disc length, and relatively massive anteriorly with a stout rostrum (Figure 6). Rostrum widest anteriorly, tapering strongly toward nasal capsules, and about one-half of total neurocranial length. Lateral rostral cartilages, as in *N. brasiliensis*, absent (this may be an artefact of radiography), but there is support lateral to rostral fontanelle as rostrum resembles a spatula anteriorly (LP, Figure 6A). Rostrum very wide lateral to rostral fontanelle, almost as wide as greatest neurocranial width at nasal capsules. Strong notch present anteriorly on each side of rostrum lateral to rostral fontanelle. Rostral fontanelle conspicuously longer than wide and relatively small, with a somewhat straight anterior contour, and resembling basibranchial copula typical of *Narcine* with a posterior notch close to the precerebral fontanelle. Precerebral fontanelle long, relatively wide and rectangular in general configuration. Lateral rostral fenestrae somewhat obscured in radiographs but appear to be present on both sides of rostrum. Basonasal fenestrae typically absent. Nasal capsules articulate laterally with well-developed antorbiral cartilages. Antorbital cartilages relatively stout at bases, expanding distally to form extensive ramifications (but not as much as in *N. brasiliensis*). Antorbitals subdivided at about one-third of their total length, where small foramina are present, and where there is a slender, but relatively elongated posterior projection. Posterior extension of antorbitals at disc margin greater than the anterior

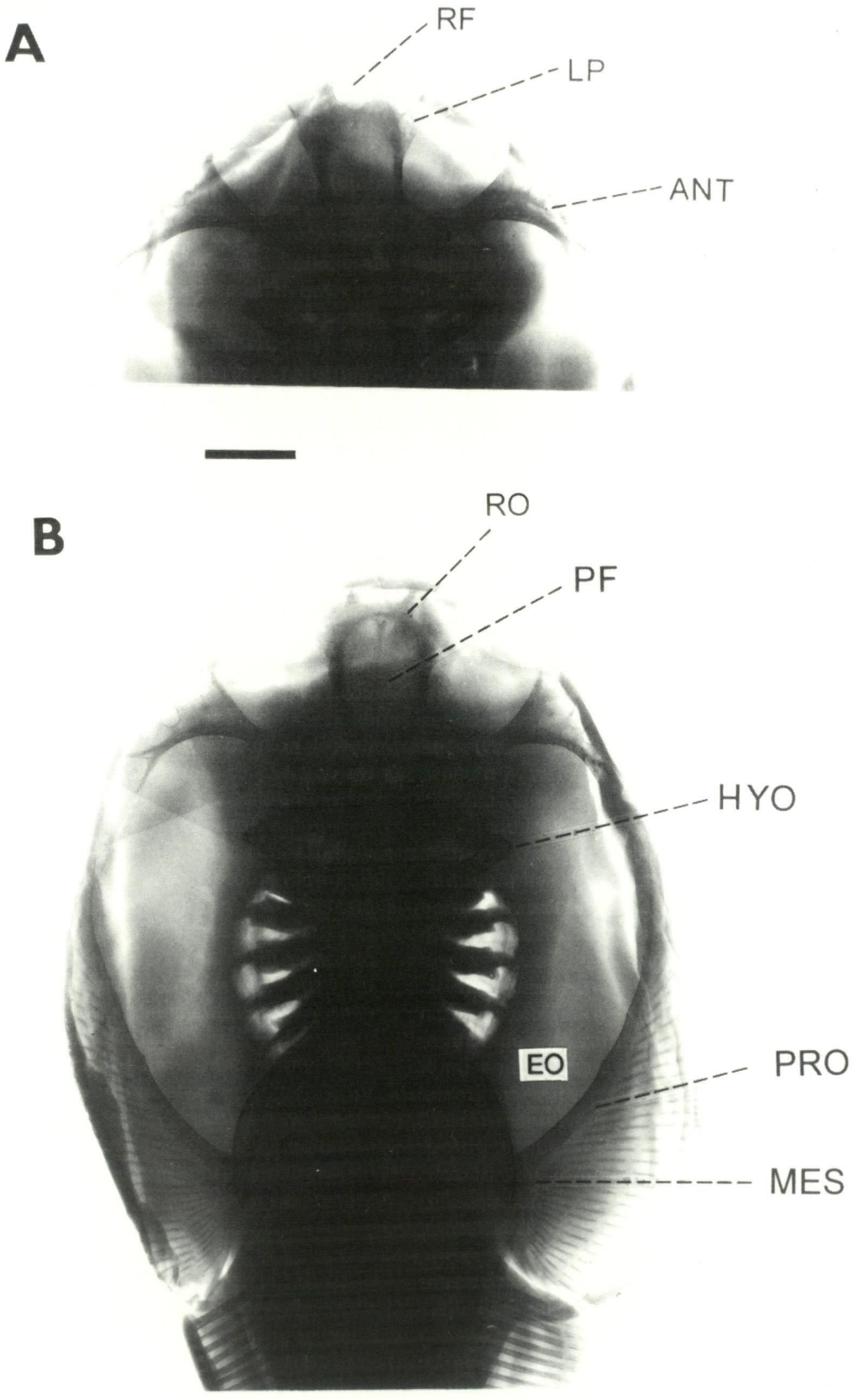

Figure 6 Radiographs of *Narcine lasti*, n. sp., showing aspects of its skeletal morphology. A) NTM 13579-004 (Arafura Sea, NT; anterior disc showing neurocranium and jaws only), and B) CSIRO CA 2597 (from off Green Head, WA; disc and anterior aspect of pelvic fins). Abbreviations: ANT, antorbital cartilage; EO, electric organ; HYO, hyomandibula; LP, lateral process of rostrum; MES, mesoptrygium; PF, precerebral fontanelle; PRO, propterygium; RF, rostral fontanelle; RO, rostrum. Scale bar = 15 mm.

antorbital segment. Orbits occupy about one-third of total neurocranial length. Otico-occipital segment relatively short and slender. Frontoparietal fontanelle and parietal fossa obscured in radiographs. Lateral knob-shaped process ventral to articulation with hyomandibulae present but not as pronounced as in *N. brasiliensis*.

Jaws stout, mandibles more robust than palatoquadrates. Both sets of jaws not fused medially and taper toward mid-line. A stout dorsal projection present laterally on each mandible. Two pairs of slender and triangular labial cartilages, one anterior to each jaw, forming "lips" that surround tooth bands. Hyomandibulae stout at bases, tapering toward jaw corners, and articulating strongly with otic region of neurocranium (Figure 6). Hyomandibulae articulate through strong ligaments distally with lower jaws for about one-third of their length. Slender prespiracular cartilages at posterior ends of hyomandibulae, projecting at right angles, and supporting anterior wall of spiracle. A pair of "palatine" cartilages visible in radiographs at level of lower jaws. Peudohyoid arch (composed of both dorsal and ventral elements) slender and inconspicuous, situated over posterior end of hyomandibulae, "wrapping" around it. Gill arches typically not wide (as in all electric rays, due to electric organs). The first and second gill arches articulate with neurocranium posterior to hyomandibulae. Both cerato- and epibranchial elements have central depressions or fossae for the insertion of depressor muscles. Last ceratobranchial morphologically distinct, being more slender and posteriorly oriented to articulate with scapulocoracoid. Pharyngobranchials small and slender, and somewhat posteriorly oriented. Pharyngobranchials contact synarcual distally (not all pharyngobranchials visible). Hypo- and basibranchial elements not discernible.

Synarcual with three and one-half vertebral centra in its posterior segment, and twelve pairs of spinal nerve foramina anterior to the first centrum. Triangular lateral stays with slightly sloping anterior margins at anterior to mid-synarcual length. Coracoid bar relatively slender in dorso-ventral view. Suprascapula also slender and articulates with scapular processes laterally. Scapulae stout, extending posteriorly, with two condylar projections present distally for articulation with pectoral pterygia (one for the propterygium and one for both the meso- and the very inconspicuous metapterygium; Figure 6B). At least three pairs of foramina present on lateral aspect of the scapular process, with a large fossa also present anteriorly on the scapulae. Propterygium divided into five segments, largest segment most basal, and almost same length as other propterygial segments combined. External margin of propterygia slightly sinuous to articulate with radials. Propterygium expanded at its base, contacting mesopterygium. Mesopterygium slender, projecting anteriorly to about one-third of length of most basal propterygial segment. Metapterygium also slender, weakly calcified and generally obscured in radiographs. Pectoral radials divided into at least four unbranched, weakly calcified segments. Pelvic girdle slender with a concave anterior margin. Pre-pelvic process elongated on each corner of girdle, extending anteriorly to almost level of scapulocoracoid (Figure 6B). A small, curved and slender iliac process present at each corner of pelvic girdle, projecting dorsally. At least three foramina present at corners of puboischiadic bar. First pelvic radial element characteristically enlarged, pelvic radials generally stout and segmented only distally (at least three segments present). Basipterygium has a sinuous external margin where it articulates with radials. Ribs present anterior to pelvic girdle and continue caudally to just posterior to it. Both dorsal fins internally similar, without enlarged basal elements. Dorsal fins have closely set radial segments. Dorsal radials of the caudal fin begin at fin origin, but elongated haemal arches present anterior to caudal fin origin. Caudal dorsal radials more slender than ventral radials. Vertebrae strongly calcified and articulate posteriorly with distal-most caudal radial.

Etymology

The specific epithet *lasti* is a patronym in honour of friend and colleague Dr. Peter R. Last, in recognition of his studies on the taxonomy and distribution of Australian elasmobranchs.

Geographical distribution

Narcine lasti has a wide distribution, occurring in the Arafura Sea (southeastern Indonesia, south of Tanimbar Island; also off the Northern Territory, Australia) and extending southwest along the continental slope of Australia as far south as off Green Head, Western Australia (Figure 7). *Narcine lasti* has been found in depths ranging from 178 to 333 m, predominantly over sandy and muddy bottoms.

DISCUSSION

Comparisons with congeners

This species was first reported by J. B. Hutchins in an unpublished report to CSIRO in 1979 (as *Narcine* sp.). Gloerfelt-Tarp and Kailola (1984) were the first to mention it subsequently, in a survey of trawled fishes of Indonesia and northwestern Australia. It was listed as "*Narcine* sp. 1" and has been suspected of being a new species for more than a decade, but only recently was it characterised in any detail (Last and Stevens, 1994; Carvalho, 1999a).

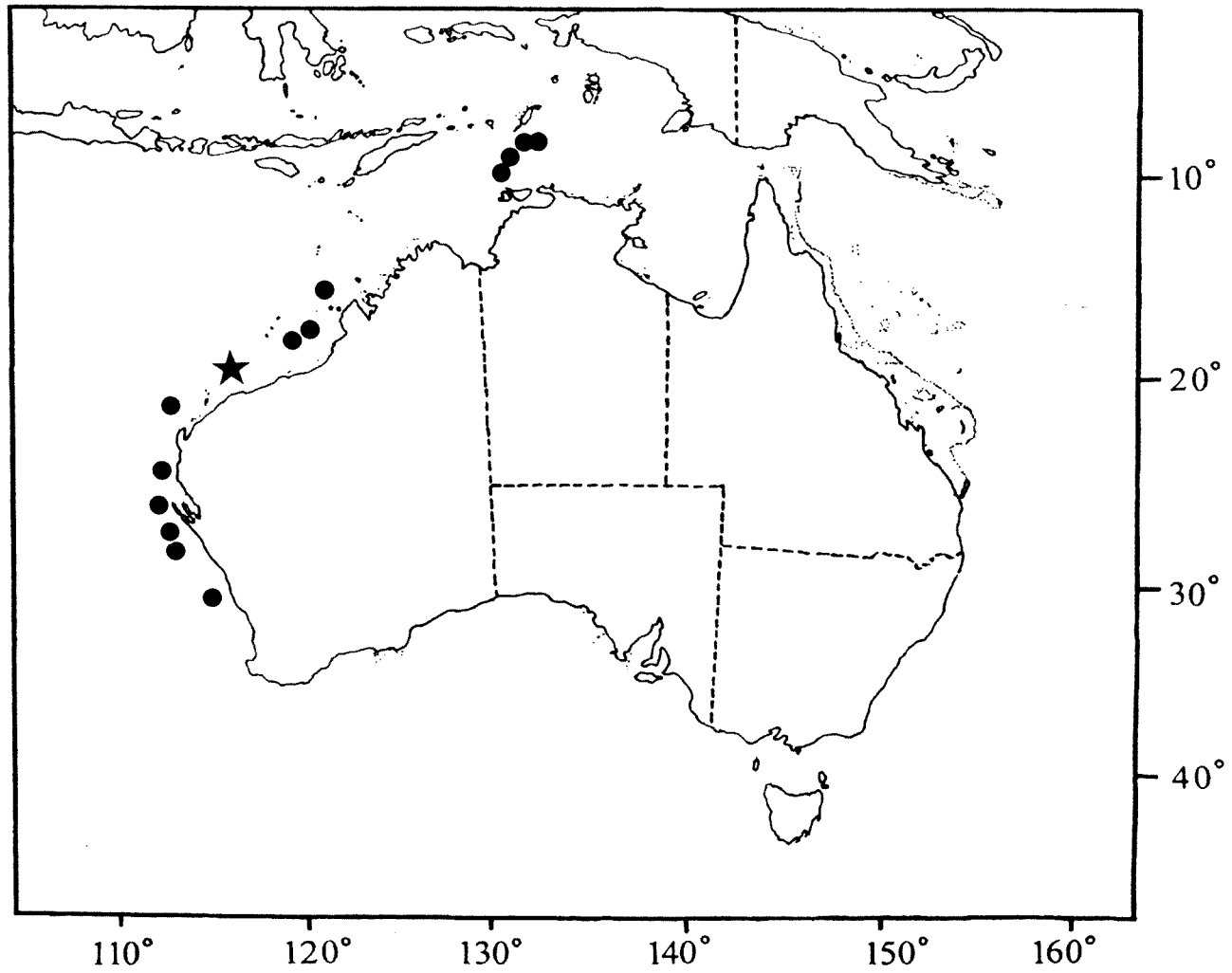

Figure 7 Distribution of *Narcine lasti*, n. sp. Closed circles may represent more than one locality. Star indicates original location of holotype.

The identification of *Narcine lasti* is usually quite straightforward. All other species of *Narcine* have a tail length less than or subequal to disc width and length, except *N. rierai* (Lloris and Rucabado, 1991) and the Australian species of *Narcine* (*N. tasmaniensis* Richardson, 1841, *N. westraliensis* McKay, 1966, and *Narcine* sp. nov. A and *Narcine* sp. nov. C *sensu* Last and Stevens, 1994, Carvalho, 1999a, and Carvalho *et al.*, 2000). From *N. rierai*, *N. lasti* is distinguished by having a nasal curtain that is much wider than long (nasal curtain is diagnostically longer than wide in *N. rierai*; Lloris and Rucabado, 1991; Carvalho, 1999a). From *N. westraliensis* and *N.* sp. nov. A, *N. lasti* is distinguished by having a uniform yellowish-brown dorsal colour pattern without any specific spotting or other distinctive markings (*N. westraliensis* has horizontal irregular stripes over disc and tail, and *N.* sp. nov. A has large spots surrounded by smaller spots over disc and tail; McKay, 1966; Carvalho, 1999a). Many other features in addition to colour pattern separate our new species from *N. westraliensis*: size and arrangement of tooth bands (tooth bands relatively wider in *N. westraliensis*, with means of 2.6 and 2.1 % of TL for upper and lower tooth bands, respectively), shape of disc (more rounded in *N. westraliensis* compared to shovel-shaped in *N. lasti*, which is reflected in the distance between snout and greatest disc width: the mean in relation to TL is 26.6 % in *N. westraliensis* compared to 32.1 % in *N. lasti*).

From *N. tasmaniensis*, *N. lasti* is distinguished by having a low, ridge-like lateral tail fold (the lateral tail fold is more broad and flap-like in *N. tasmaniensis*), a relatively more slender disc (disc width with a mean of 40.3 % of TL in *N. lasti*, compared to a mean of 43.4 in *N. tasmaniensis*), a greater preorbital snout length (mean is 10.1 % of TL in *N. lasti*, compared to 7.8 in *N. tasmaniensis*) and by a lighter dorsal colouration (usually a dark chocolate brown in *N. tasmaniensis* as opposed to yellowish brown in *N. lasti*; Carvalho, 1999a).

Narcine lasti is distinguished from *Narcine* sp. nov. C by presenting a relatively wider and longer disc

(with means of 40.3 and 42.1 % of TL, respectively, in *N. lasti*, compared to means of 38.4 and 40.2 % of TL in *N.* sp. nov. C), and by having a light yellowish-brown background (extending into preorbital snout region) compared to, in *N.* sp. nov. C, a slightly darker uniform brown background colour with a preorbital snout region distinctly lighter in many specimens. Carvalho (1999a) also documents differences among these two species in numbers of tooth rows, distance between dorsal fins and possibly size at maturity. Furthermore, *Narcine lasti* and *Narcine* sp. nov. C are entirely separated geographically, the former occurring off the Western Australian coast and in the Arafura Sea, while the latter is restricted to relatively deep waters off the Queensland coast. However, both species are very similar in overall aspect sharing a relatively long tail and shovel-shaped disc, and together with *Narcine tasmaniensis* appear to form a species-group (Carvalho, 1999a).

Comments on sexual maturity

Judging from clasper rigidity, sexual maturity for males appears to occur at around 240 mm TL, as a 234 mm TL male examined is close to being sexually mature (assuming that sexual maturity closely follows clasper rigidity, as is usually the case in electric rays). However, a few examined male specimens larger than 265 mm TL have somewhat "soft" claspers, but appear to be very close to sexual maturity, if not already capable of reproduction (one specimen of 297 mm TL with relatively soft claspers was also examined). Sexual maturity for females putatively occurs at similar sizes. A 331 mm TL female was found to contain two late-term embryos, one in each uterus, as well as one large egg mass without an associated visible embryo in the right uterus. The late-term embryos measured 72 and 77 mm TL (consisting of a male and female specimen, respectively), both with yolk-sacs and yolk-stalks still attached, but were undoubtedly close to birth. Egg masses were found in both uteri in other large females that also contained late-term pups, corroborating that both uteri are functional and synchronous in *N. lasti*. The uteri of females of *N. lasti* are extremely thin-walled and somewhat transparent, apparently without any nutrition-supplying function.

Non-type material examined (48 specimens, 75–361 mm TL)

Western Australia – AMS I 22821-007 (5), 204 mm total length juvenile male and 227 to 255 mm total length pre-adult females, 18°16'S, 118°12'E, 320 m, FRV Soela, J. Paxton, 10 April 1982; CSIRO CA327, 198 mm total length pre-adult female; CSIRO CA330, 360 mm total length adult female, "Northwest Shelf, WA," FRV Courageous, v. 1978; CSIRO CA347, 245 mm total length pre-adult male; CSIRO H 1035 (2), 2 late-term embryos extracted from uteri of 331 mm total length female (H1035-01), each approximately 75 mm in total length (not measured further; data as in paratype H1035-01; CSIRO CA1486, 206 mm total length pre-adult male; CSIRO H2547-10, 321 mm total length adult female, from west of North West Cape, 21°37'S, 113°59'E, 209–215 m, FRV Southern Surveyor, SS 0191/7, 24 January 1991; CSIRO CA2812, 298 mm total length adult female, from north of Forestier Island, 18°10'S, 118°20'E, 300 m, FRV Soela, sta. 2/82/36, 10 April 1982; CSIRO CA2813, 258 mm total length pre-adult female (data as in CA2812); CSIRO CA2873, 315 mm total length adult female, from north of Forestier Island, 18°31'S, 118°09'E, 200 m, FRV Soela, sta. 2/82/14, 2 April 1982; CSIRO H3054-03 (3), 361 mm total length adult female with 2 late-term embryos (not measured), from north of Carnarvon, 24°40'S, 113°43'E, 225 m, 28. ix. 1990; CSIRO H4031-81, 117 mm total length pre-adult male, from north of Cape Lambert, 18°57'S, 117°14'E; CSIRO H4070-09, 162 mm total length pre-adult male, from northwest of Port Hedland, 18°12'S, 118°14'E, 269 m, SS 8/95/123; CSIRO CA4361, 216 mm total length pre-adult female, from north of Port Hedland, 18°11'S, 118°16'E, 304 m, FRV Soela, S 01/84/29, 2 February 1984; CSIRO CA4367, 261 mm total length pre-adult male, from southeast of Mermaid Reef, 17°18'S, 120°09'E, 304 m, FRV Soela, S 0184/39, 4 February 1984; NMV A9656, 254 mm total length pre-adult or adult male, from 85 km southwest of Geraldton, 29°15'S, 113°56'E, 320–325 m; NTM S12641-021, 297 mm total length adult male, from northwest of Lynher Bank, 14°50'S, 121°35'E, 275–280 m, J. Baillie, 15 December 1989; NTM S14266-006, 202 mm total length pre-adult female, from northwest of Houtman Abrolhos, 28°15.9'S, 113°19.5'E, 240–333 m, P. Alderslade, 11 July 1987; WAM P 26270-010 (2), 214 mm TL, 244 mm TL, 230 km NW of Beagle Island, WA, 15°30'S, 120°58'E, 280–320 m, FRV Courageous (P. Brown), shot 0751, 28 June 1978; WAM P 28105-003 (2), 179 mm TL, 184 mm TL, 100 km SW of Rowley Shoals, WA, 18°10'S, 118°16'E, 276–278 m, N. Sinclair and P. Berry, 24 August 1983; WAM P 30581-004 (2), 238 mm TL, 244 mm TL, 17°17'00"S, 120°11'00"E, 304–305 m, FRV Soela, 4 February 1984.

Northern Territory – NTM S13065-002 (4), 275 mm total length adult male, 246–262 mm total length pre-adult to adult females, from north of Bathurst Island, 09°49'S, 130°15'E, 260 m, FRV Invincible, D. Evans, 12 December 1990; NTM S13147-013 (4), 272–285 mm total length pre-adult to adult males, 312–321 mm total length adult females, 09°37'S, 130°26'E, 255 m, FRV Invincible, D. Evans, 9 December 1990; NTM S13578-009, 311 mm total length adult female, 08°55.3'S, 133°41.1'E, 179–187 m, RW 92-66, R. Williams, 20 October 1992; NTM

S13579-004, 250 mm total length pre-adult female, 09°01'S, 133°19.7'E, 193–195 m, RW 92-67, R. Williams, 20 October 1992; NTM S13580-039 (4), 241–267 mm total length pre-adult males, 325–328 mm total length adult females, 09°04.7'S, 133°04.7'E, 179–205 m, RW 92-68, R. Williams, 20 October 1992.

Indonesia – MNHN 1996-1557 (4), 144 to 162 mm total length pre-adult females, 145 mm total length pre-adult male, from off Tanimbar Island, 9°26'S, 131°13'E, 225 m, R/V Karubar, sta. CP86, 4 November 1991.

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