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A NEW SPECIES OF ELECTRIC RAY OF THE GENUS *NARCINE* HENLE, 1834 FROM THE SOUTH-WESTERN INDIAN OCEAN (CHONDRICHTHYES: TORPEDINIFORMES: NARCINIDAE)

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A new species of electric ray of the genus *Narcine* Henle, 1834 is described from seven specimens collected from two localities off the western coast of Madagascar, in the Moçambique Channel. *Narcine insolita*, sp. nov. is distinguished from all other species of the genus by the unique presence of a very prominent first dorsal fin that is much greater than the second dorsal fin in both height and length of base. A unique combination of characters further distinguishes *N. insolita*, including large and bulging eyes, large circular spiracles with elevated rims, interorbital distance much greater than interspiracular distance, rounded cusplets lateral to principal cusp on teeth of inner tooth rows, broadly rounded tooth bands, dorsal colouration composed of a yellowish brown background with large dark brown to reddish brown blotches at disc margins and over dorsal and caudal fins, and numbers of precaudal and total vertebral centra. *N. insolita* is similar but distinct from the recently described *Narcine oculifera* from the Gulfs of Oman and Aden, with which it is compared. An additional specimen of *Narcine* from the coast of Moçambique also presents features in common with our new species. However, it is not currently included in *N. insolita*, because it lacks its autapomorphic dorsal fin proportions. This specimen probably represents a further undescribed species of *Narcine* from the south-western Indian Ocean, but more specimens from Moçambique are required for further evaluation. The new species represents only the third described species of *Narcine* from the western Indian Ocean.

Key words: Moçambique Channel, *Narcine*, new species, numbfish, south-western Indian Ocean, taxonomy

Electric rays are a moderately diverse group of batoids that occur circumglobally in most warm to subtemperate marine waters. They are noteworthy for having electrogenic or torporific qualities, which have been known since antiquity. Electric rays are morphologically very distinctive and easily separated from other batoids, presenting well-developed pectoral electric organs derived from branchial musculature, smooth skin devoid of dermal denticles or spines, and a highly modified posteriorly arched shoulder girdle, among other characters (Bigelow and Schroeder 1953, Compagno 1973). Currently, 10 genera and some 50 described species of electric rays are recognized as valid, but the taxonomic status, correct identification and distribution of many of these is problematical (Carvalho 1999, Carvalho *et al*. 2000).

Henle (1834) originally included in his description of *Narcine* the south-western Atlantic species *Torpedo brasiliensis* von Olfers, 1831 (type-species), *Raja timlei* Bloch and Schneider, 1801 and his new species *Narcine indica* Henle, 1834 (=*Raja timlei* Bloch and Schneider, 1801; Carvalho 1999) from India, and *Raja capensis* Gmelin, 1789 (= *Narke capensis*) from South Africa. *Raja dipterygia* Bloch and Schneider, 1801 (= *Narke dipterygia*), also from India, was included as a doubtful species. Henle (1834) distinguished species of *Narcine* from other electric rays on the basis of anterior disc shape, configuration of the mouth, arrangement of teeth positioned externally on tooth bands, and unique antorbital cartilages. Carvalho (1999) reviewed the genus, colloquially known as "numbfish" or "lesser" electric rays, and found that 26 nominal species can be correctly included in it, but only 11 of which are valid. Carvalho (1999) also recognized nine new species of *Narcine* (several of these are currently being described elsewhere), bringing the total number of species in the genus to 20. The new species of *Narcine* described below is done in advance of the publication of a full generic revision by the senior author.

Species of *Narcine* are more diverse in shallow waters of the tropical West Indo-Pacific region, but only one previously described species is present along the south-eastern coast of Africa in the Western Indian Ocean (*Narcine rierai*; Lloris and Rucabado 1991, Compagno 1995). The first correct record of *Narcine* from eastern Africa, however, was by Norman (1939) from off northern Somalia in the Gulf of Aden (repeated in Fowler 1956; see Carvalho *et al.* 2002).

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Table I: Measurements for *Narcine insolita*, sp. nov. Means and standard deviations (*SD*) were extracted from all specimens (*n*). Holotype: MNHN 1996–1555; paratypes: MNHN 1996–1554, MNHN 1996–1553, MNHN 1996–1552, MNHN 1996–1551, MNHN 1996–1550, MNHN 1996–1549. See text for explanation of abbreviations

Parameter	*n*	Holotype	Paratypes	Mean	*SD*
TL (mm)	7	356.0	135.0–266.0	–	–
	Percentage of total length				
DW	7	43.5	40.4–54.9	48.0	5.3
DL	7	43.5	46.4–50.9	47.5	2.3
PBS	7	8.7	9.7–11.4	10.2	0.9
POS	7	12.3	13.6–15.6	14.2	1.1
PNS	7	9.0	10.4–11.6	10.7	0.8
SDW	7	28.1	26.3–32.5	28.8	2.2
IOD	7	7.4	5.6–7.8	7.0	0.7
EL	7	3.3	3.6–4.7	4.0	0.5
ISD	7	5.2	5.5–6.0	5.6	0.2
SPL	7	2.6	2.3–4.1	3.2	0.6
SPW	7	2.9	2.8–3.8	3.2	0.4
MW	7	6.6	6.8–7.6	7.1	0.4
UTB	7	2.9	2.5–3.4	3.0	0.3
LTB	7	2.5	2.6–3.4	2.9	0.3
NCW	7	4.6	5.3–5.5	5.3	0.3
NCL	7	2.2	2.1–2.9	2.5	0.3
DBN	7	5.0	5.3–5.9	5.5	0.3
FGO	7	10.3	10.5–13.6	11.8	1.3
LGO	7	6.9	5.9–9.0	7.3	1.1
BBL	7	7.9	7.7–9.2	8.2	0.5
PFL	7	19.9	13.2–21.4	17.9	2.8
PFW	7	29.2	26.5–35.8	32.0	3.4
AMP	7	10.1	11.3–15.6	12.5	1.8
PMP	7	16.6	12.6–17.1	15.1	1.9
TW	7	15.6	15.4–19.7	16.7	1.6
HFD	7	13.5	11.3–16.9	13.9	1.9
LFD	7	7.6	8.4–10.7	9.1	1.0
HSD	7	10.1	8.3–13.3	10.8	1.7
LSD	7	6.2	6.8–8.5	7.2	0.7
LDC	7	15.7	14.6–19.4	17.2	1.7
LVC	7	17.1	14.6–17.3	16.2	1.0
HDC	7	6.5	4.1–7.2	5.4	1.2
HVC	7	7.3	4.6–6.7	5.7	1.0
HC	7	15.7	10.2–16.2	13.3	2.5
DBD	7	7.9	6.9–8.7	7.8	0.7
SDC	7	6.4	5.5–6.7	6.2	0.4
SCL	7	43.5	45.1–47.1	45.6	1.2
CLC	7	50.6	47.7–50.4	49.5	1.1
SFD	7	48.3	48.9–53.0	50.3	1.7
EOL	7	22.8	19.3–23.2	21.7	1.4
EOW	7	7.9	8.3–11.7	10.2	1.5
CL	4	–	7.3–12.8	9.7	2.4

Fourmanoir (1963) reviewed the batoid fauna of Madagascar and included in it two species of electric rays of the genus *Torpedo*, but no species of *Narcine*. The first collections of *Narcine* from Madagascar were made during shrimp fisheries surveys undertaken by the Office de la Recherche Scientifique et Technique Outre Mer (ORSTOM, presently Institut de Recherche pour le Développement [IRD]) between 1969 and 1975. Excellent rajoid material was also obtained during those cruises, revealing new records and species of skates (e.g. Séret 1986a, b). A new species of *Narcine* known from seven specimens from western Madagascar, collected during those surveys, is described here and compared to another specimen of *Narcine* recently collected in the Moçambique Channel, with which it does not appear to be conspecific. Comparisons are also provided with another very similar species of *Narcine* that occurs off the coasts of Oman and Somalia (*N. oculifera*).

MATERIAL AND METHODS

Measurements were made with electronic calipers in a straight line, point-to-point to the nearest tenth of a millimetre. When specimens were large or required measurements of approximately 150 mm or more, a steel ruler or tape measure was used, and expressed to the nearest mm, following Carvalho (1999). All measurements are presented in Table I, and are expressed as proportions of total length (*TL*). Abbreviations for measurements are as follows (for more detailed description see Carvalho 1999): total length (*TL*, in mm); disc width (*DW*); disc length (*DL*); preorbital snout length (*PBS*); preoral snout length (*POS*); prenasal snout length (*PNS*); snout to greatest disc width (*SDW*); interorbital distance (*IOD*); eye length (*EL*); interspiracular distance (*ISD*); spiracle length (*SPL*); spiracle width (*SPW*); mouth width (*MW*); upper tooth band width (*UTB*); lower tooth band width (*LTB*); nasal curtain width (*NCW*); nasal curtain length (*NCL*); distance between nostrils (*DBN*); distance between first gill openings (*FGO*); distance between last gill openings (*LGO*); branchial basket length (*BBL*); pelvic fin length (*PFL*); pelvic fin width (*PFW*); anterior margin of pelvic fin (*AMP*); posterior margin of pelvic fin (*PMP*); tail width (*TW*); height of first dorsal fin (*HFD*); length of first dorsal fin (*LFD*); height of second dorsal fin (*HSD*); length of second dorsal fin (*LSD*); length of dorsal lobe of caudal fin (*LDC*); length of ventral lobe of caudal fin (*LVC*); height of dorsal lobe of caudal fin (*HDC*); height of ventral lobe of caudal fin (*HVC*); height of caudal fin (*HC*); distance between dorsal fins (*DBD*); distance between second dorsal and caudal fins (*SDC*); snout to cloaca length (*SCL*); cloaca to caudal fin length (*CLC*); snout to first dorsal fin length (*SFD*); electric organ length (*EOL*); electric organ width (*EOW*); clasper length (*CL*).

Counts were taken directly from radiographs and are summarized in Table II. Meristic characters are also

Table II: Counts for *Narcine insolita*, sp. nov. (B–F are paratypes). A–Holotype MNHN 1996–1555; B–MNHN 1996–1554; C–MNHN 1996–1552; D–MNHN 1996–1551; E–MNHN 1996–1550; F–MNHN 1996–1549. See text for explanation of abbreviations

Parameter	A	B	C	D	E	F	Range
TL (mm)	356	266	232	151	151	135	135–356
PRO	14	14	15	16	16	17	14–17
MES	10	10	11	8	11	10	8–11
MET	5	5	6	3	3	2	2–6
TPR	29	29	32	27	30	29	27–32
PVR	20	16	19	19	18	17	16–20
FDR	9	10	9	9	8	9	8–10
SDR	*	10	6	6	9	6	6–10
DCR	22	22	19	19	19	19	19–22
VCR	24	29	22	23	26	28	22–29
TCR	46	51	41	42	55	47	41–55
UTR	24	23	19	18	19	14	14–24
LTR	21	23	23	18	19	11	11–23
TC	29	28	27	28	25	27	25–29
PC	70	68	70	71	68	78	68–71
CC	23	25	22	24	26	22	22–26
TV	122	121	119	123	119	127	119–127
R	7	6	7	6	7	6	6–7

* Counts not available in radiographs

based on Carvalho (1999): propterygium radials (PRO); meso-pterygium radials (MES); metapterygium radials (MET); total pectoral radials (TPR); 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); total caudal radials (TCR); exposed vertical tooth rows on upper tooth band (UTR); exposed vertical tooth rows on lower tooth band (LTR); trunk vertebral centra (TC); precaudal vertebral centra (PC); caudal vertebral centra (CC); total vertebral centra (TV); ribs (R). The division of the vertebral column into trunk and precaudal centra is based on the pelvic girdle, because it was not always possible to discern monospondylous to diplospondylous transitions in radiographs (pelvic girdle may lead to small error in other batoids, such as skates, because of possible fluctuations in pelvic girdle placement, but this does not appear to be the case in *Narcine*). Tooth counts were taken under a stereomicroscope and follow the method outlined in Stehmann (1978). Only exposed tooth rows were counted, i.e. rows, visible on tooth bands when the mouth is closed (dissection or radiography is necessary to count internal tooth rows because of the strong labial cartilages immediately lateral to the tooth bands).

Comparative material of all species of *Narcine* was used for the present description, and is listed in Carvalho (1999). Institutional abbreviations follow Leviton *et al*. (1985). The skeletal description is not meant to be exhaustive and is restricted to features that can be observed in dorso-ventral view (taken from radiographs, mostly of the holotype). Terminology for anatomical elements follows Carvalho (1999). Terminology for the lateral-line canal system is according to Chu and Wen (1979), with the following exception: the anterior extension of the infraorbital canal beyond the hyomandibular canal is designated "antorbital canal".

SYSTEMATIC ACCOUNT

Order Torpediniformes Berg, 1940
Family Narcinidae Gill, 1862
NUMBFISH

DIAGNOSTIC CHARACTERS

Small to medium-sized batoids (maximum total length 15–75 cm) with large, oval, rounded to shovel-shaped pectoral discs and stout shark-like tails; disc and tail of equal length, or tail longer than disc length or disc width. Trunk depressed and flattened, not shark-like. Disc usually thick and fleshy laterally. Precaudal tail moderately depressed, usually with variously developed lateral ridges on sides; tail abruptly narrower than trunk. Head broad and depressed; snout moderately elongated, broadly rounded or obtusely rounded-angular; supported by large anteriorly expanded and relatively wide rostral cartilage and by anteriorly expanded, bifurcate antorbital cartilages. Body entirely naked above and below, without dermal denticles or thorns. Sensory pores of both ampullary and lateral-line systems present dorsally over disc and laterally on tail (lateral-line pores), but only ampullary pores present ventrally. Five small ventral gill openings, not visible in lateral view; no gill sieves or rakers on internal gill slits. Eyes dorsally on head and just anterior and partly medial to spiracles. Spiracles with or without elevated rims or small papillae (these never very elongated when present), and with internal pseudobranchial folds on anterior aspect of inner spiracular wall. Mouth transverse and straight, with strong labial folds and a prominent circumoral groove around its periphery. Nostrils just anterior to mouth and usually separated from it by much less than internarial space, connected by broad nasoral grooves with mouth; anterior nasal flaps usually short but medially expanded and fused into a broad nasal curtain that may slightly overlap mouth. Oral teeth small, with a rounded to oval base and short to moderately long cusp, either blunt or sharp, not laterally expanded or plate-like, similar in shape and varying

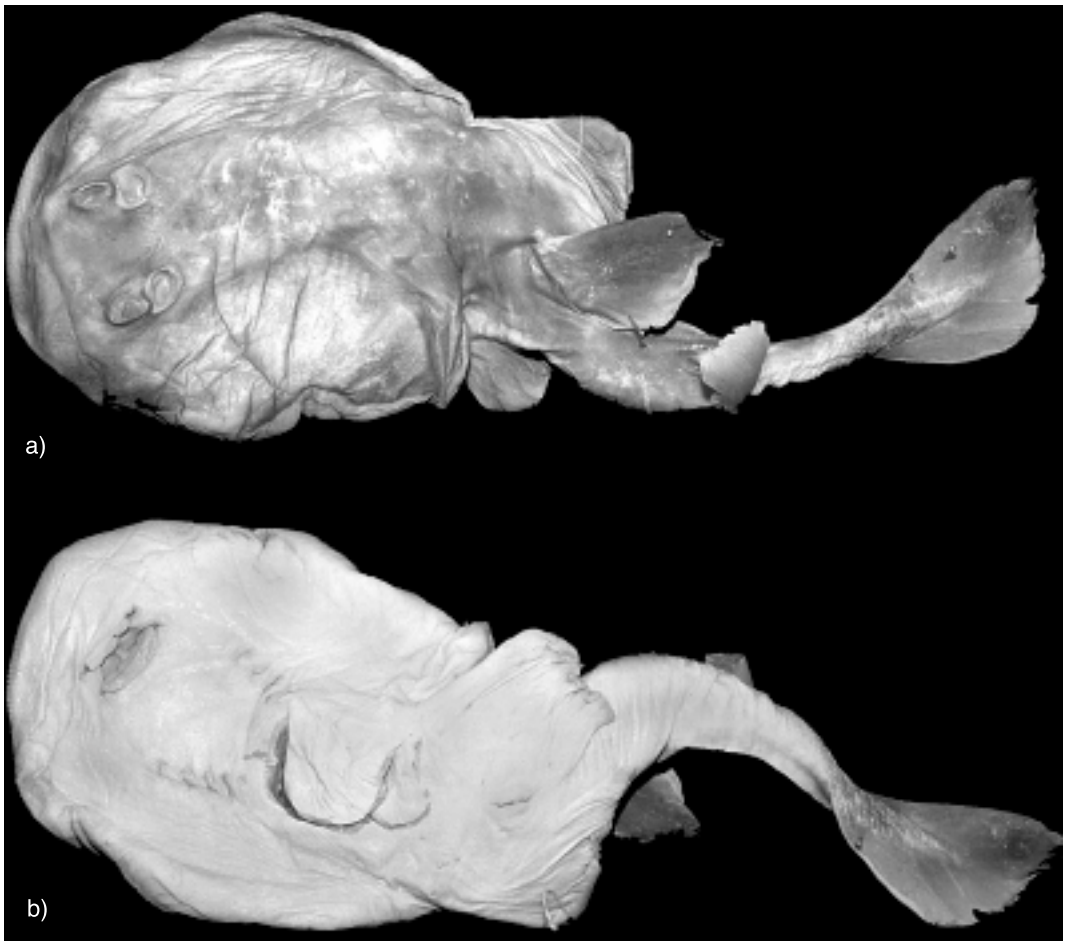

Fig. 1: Holotype of *Narcine insolita*, sp. nov. (MNHN 1996–1555, 356 mm *TL*; north-western Madagascar, 15°20´S, 46°11.5´E, depth 170–175 m) in (a) dorsal and (b) ventral views

from 12–40 rows in either jaw. Teeth and part of tooth bands (external oral integument) may remain exposed when mouth is closed. Large kidney-shaped electric organs at bases of pectoral fins, generally visible through skin. Pelvic fins low, subangular or rounded, not divided into distinct anterior and posterior lobes. Two moderately large, usually equal-sized and widely separated or close-set dorsal fins present; dorsals of similar angular or rounded-angular shape with distinct apices, anterior, posterior and inner margins, and free rear tips; dorsal fins not falcate. First dorsal fin originates behind anterior half of total length. Caudal fin large and fan-like or with broadly rounded ventral margin, not shark-like, asymmetrical or symmetrical, with vertebral axis hardly raised above body axis.

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: nasal curtain with straight posterior margin, without median posterior flap (pre-

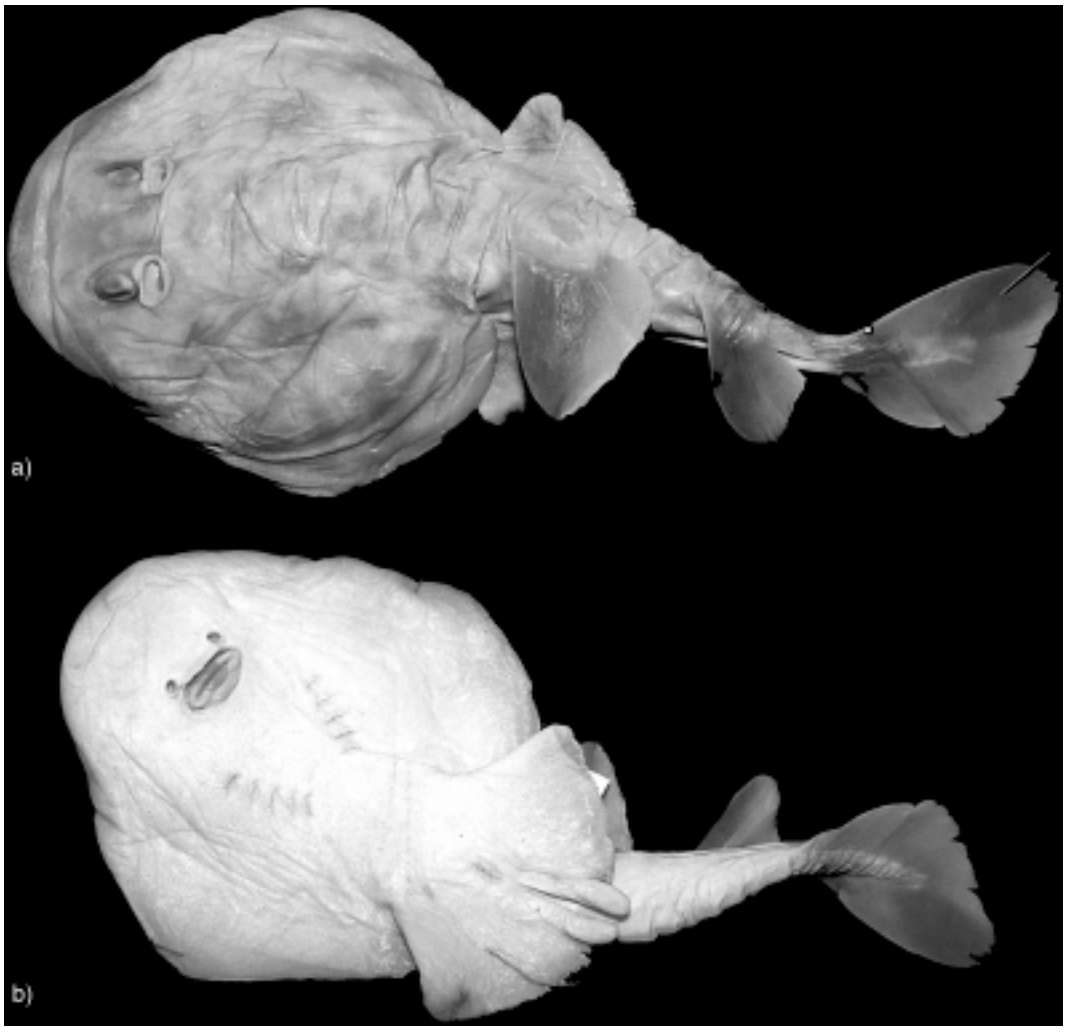

Fig. 2: Paratype of *Narcine insolita*, sp. nov. (MNHN 1996–1554, 266 mm *TL*; north-western Madagascar, 15°21´S, 46°12.5´E, depth 150 m) in (a) dorsal and (b) ventral views. Note that caudal fin is pointing downwards in (b)

sent 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 externally 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 hypothesized as supporting the monophyly of *Narcine* (modified from Carvalho 1999): fused and paired hypobranchial plates with sinuous external margins, articulating with ceratobranchials 2–4; facio-palatine foramen present within the orbit; lack of contact between ceratohyal and the component tentatively identified as being the first hypobranchial.

Narcine insolita, new species
(Figs 1–6, Tables I–II)

Narcine sp. B — Baranes and Randall (1989): 98, 99 (listed in material examined; Madagascar).
Narcine sp. nov. E — Carvalho (1999): 243–250, Figs 88–90 (in part; diagnosis, description, distribution, colour photographs; Madagascar) – Carvalho *et al.* (2002): 143–144, Table III (compared to *N. oculifera*, described as new).

Holotype

MNHN 1996–1555, adult female, 356 mm *TL*, north-western Madagascar, 15°20´S, 46°11.5´E, depth 170–175 m, Sta. CH 130, R.V. *Vauban*, Field no. F 516, shrimp trawl, 19. i. 1975. (Fig. 1).

Paratypes (6 specimens)

MNHN 1996–1549, juvenile male, 135 mm *TL*, south-western Madagascar, 23°12.5´S, 43°32.5´E, depth 150 m, Sta. 14, "La Barbade," Field no. 777, 31. iii. 1969; MNHN 1996–1550, juvenile male, 151 mm *TL*, same data as MNHN 1996–1549, Field no. 776; MNHN 1996–1551, juvenile female, 151 mm *TL*, same data as MNHN 1996–1549, Field no. 778; MNHN 1996–1552, pre-adult female, 232 mm *TL*, same data as MNHN 1996–1549, Field no. 779; MNHN 1996–1553, pre-adult male, 257 mm *TL*, north-western Madagascar, 15°20´S, 46°12´E, depth 150 m, Sta. 73/122, "FAO 60" Field no. 1634, 12. x. 1973 (Fig. 3); MNHN 1996–1554, pre-adult male, 266 mm *TL*, north-western Madagcasar, 15°21´S, 46°12.5´E, depth 150 m, Sta. CH 52, R.V. *Vauban*, Field no. F 325, 8. xi. 1972 (Fig. 2).

DIAGNOSIS

A south-western Indian Ocean species of *Narcine* distinguished from all congeners by the unique presence of a very large and prominent first dorsal fin that is conspicuously taller, larger and with a longer base than the second dorsal fin. The following unique combination of characters further diagnoses this new species: spiracles large and conspicuously rounded, not projecting anteriorly lateral to eyes, and with elevated rims all around; interspiracular distance much smaller than interorbital distance; small, broadly rounded lateral cusplets adjacent to principal cusp on teeth of more concealed inner rows; upper and lower tooth bands equal in width and broadly circular in outline; dorsal colouration composed of a yellowish-brown background with darker brown to reddish-brown irregular blotches on disc margins, posterior disc and anterior margin of snout, also with darker brown blotches on anterior portion of dorsal and caudal fins, at caudal apex, and laterally on tail at level of dorsal fins; 68–71 precaudal vertebrae and 119–127 total vertebrae.

DESCRIPTION

Measurements are presented in Table I and meristic counts in Table II.

External morphology — Disc about as wide as long, oval to heart-shaped in outline. Disc length 43.5–50.9% of *TL*, disc width 40.4–54.9% of *TL*. Disc widest just posterior to its mid-length, barely overlapping origin of pelvic fins posteriorly. Anterior border of snout diagnostically ovoid. Preorbital snout area not greatly elongated, ranging from one-fourth to one-fifth in disc length. Disc with only a small free edge posteriorly. Disc margins conspicuously fleshy and thick. Electric organs relatively wide, about half as wide as long; electric organs originate posterior to level of nostrils and extend to between one-fourth and one-fifth of disc length; outline of electric organs only faintly visible both ventrally and dorsally. Gill slits relatively wide, largest gill slit about equal to width of lower tooth band, and first three gill slits situated lateral to level of mouth corners and nostrils. Gill slits relatively close together; branchial basket length only 7.7–9.2% of *TL*. Eyes and spiracles closely adjacent; eyes conspicuously large and bulging. Spiracles relatively large, and rounded to slightly oblique (in some specimens just wider than long), with highly elevated, smooth and conspicuous rims all around, including anterior borders. Spiracles with well defined anterior margins, not extending forward lateral to eyes. Interspiracular distance much smaller than interorbital distance. Small, knob-shaped and inconspicuous pseudobranchial folds present inside spiracle on anterior spiracular wall (12 in each spiracle for holotype, but 14 in paratype MNHN 1996–1554).

Nasal curtain short and wide (Fig. 4c), entirely covering upper tooth band in well preserved speci-

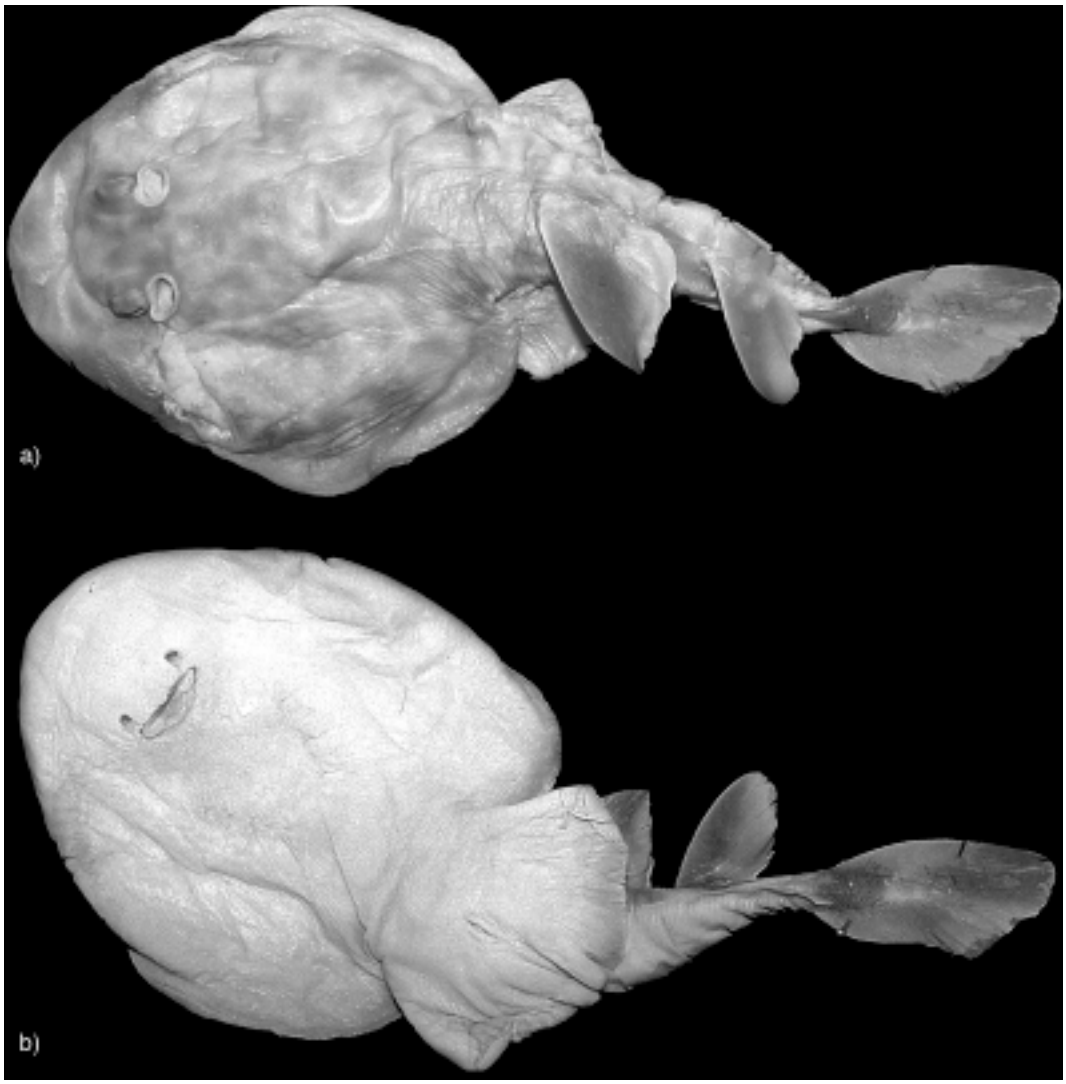

Fig. 3: Paratype of *Narcine insolita*, sp. nov. (MNHN 1996–1553, 257 mm *TL*; north-western Madagascar, 15°20´S, 46°12´E, depth 150 m) in (a) dorsal and (b) ventral views

mens; posterior margin of nasal curtain relatively straight. Ampullary pores of ventral snout region not extending posterior to level of nostrils. Nostrils circular, with elevated narial flaps only on posterior margins. Mouth corners rounded and on more or less same vertical level as nostrils. Upper and lower tooth bands of equal width, semi-circular in outline, with rounded anterior (on upper tooth band) and posterior (on lower tooth band) margins; tooth bands easily detach from underlying integument. Teeth in 14/11–24/23 rows (including juveniles and adolescent specimens; adult female with 24/21 rows, adolescent [almost adult] male with 23/23 rows). Teeth with relatively wide crowns and, on inner rows, small, generally broadly rounded cusplets or projections lateral to more developed central cusp; central cusp more pronounced on inner rows of both males and females (exposed teeth usually with blunt or completely worn

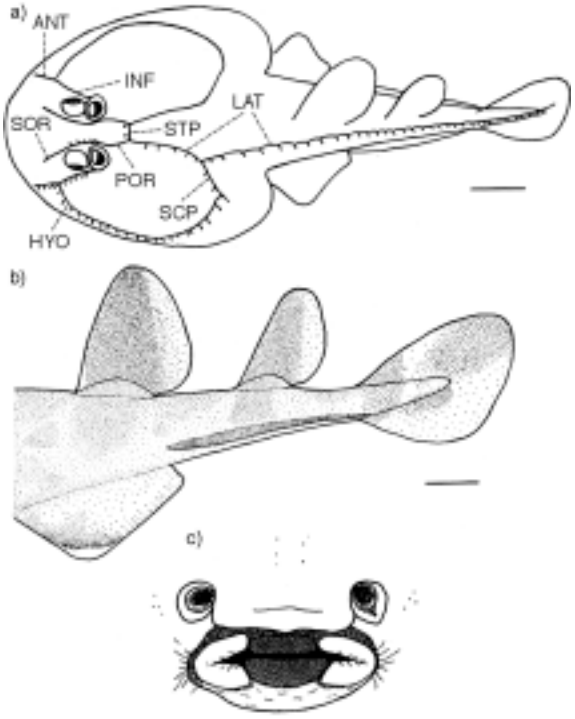

Fig. 4: *Narcine insolita*, sp. nov: (a) lateral-line sensory canals (scale bar = 20 mm); (b) lateral view of tail region (scale bar = 8 mm); (c) nasoral region, with nasal curtain somewhat shrunken and slightly pulled towards top. Abbreviations: ANT – antorbital canal; HYO – hyomandibular canal; INF – infraorbital canal; LAT – lateral canal; POR – postorbital canal; SCP – scapular canal; SOR – supraorbital canal; STP – supratemporal canal

down cusps); teeth in smallest specimen examined (juvenile male 135 mm *TL*) already with clearly noticeable central cusp on inner rows.

Pelvic fins much wider than long, with slight free edge posteriorly. Pelvics not connected ventrally at posterior margin, and do not reach level of posterior margin of first dorsal fin. Tail length between cloaca and caudal fin tip (47.7–50.6% of *TL*) greater than snout to cloaca length (43.5–47.1% of *TL*). Tail base stout, slightly wider than tall and sub-circular in cross section. Lateral tail folds well developed and flap-like, extending from level ventral to posterior first dorsal fin base to caudal base. First dorsal fin origin at mid-length of pelvic fin. Dorsal fins markedly tall and broad, very wide, especially first dorsal fin (Fig. 4b). First dorsal fin much taller and larger than second dorsal, with very rounded apex and pronounced free lobe posteriorly. Second dorsal fin about one-half as broad as first dorsal, with more oval apex and smaller free lobe posteriorly. Distance between dorsal fins more or less equal to distance between second dorsal and caudal fin. Caudal fin with well developed dorsal and ventral lobes, these with similar proportions. Dorsal lobe with a sloping anterior margin up to approximately its mid-length, where it levels slightly; caudal fin tip rounded to oval. Ventral lobe tall, with broadly rounded margin. Both dorsal and ventral lobes originate at same level on caudal base. Claspers of males (all pre-adult) extend just beyond pelvics posteriorly.

Pores and canals of lateral-line system (Fig. 4a) not clearly visible in larger specimens without specific preparation, and more easily observed in smaller specimens with faded pigmentation. Canals of the lateral-line system are relatively wide, composed of antorbital, supraorbital, postorbital, infraorbital, rostral, supra-temporal, hyomandibular (looping around most of electric organs), scapular and lateral tail canals. Infra-orbital canal not projecting posterior to spiracles or extending in between spiracles and eyes (no pores or canals present in this region), as in *N. brasiliensis* and other species of *Narcine*. Canals with relatively short branches. Ampullary pores only faintly visible externally, radiating in more or less parallel rows from nasal curtain forward to ventral snout margin; distance between rows increasing closer to snout tip. Two prominent endolymphatic pores present posterior to spiracles and anterior to supratemporal canal.

Colouration — Dorsal colouration in preserved specimens with a yellowish-brown background and darker brown to reddish-brown irregular blotches of varying size (usually larger than eye diameter) on disc margins, lateral to eyes, on anterior snout region, at level of scapulocoracoids and at posterior disc margins. Light brown to reddish-brown faint and irregular reticulations also present dorsally over disc. Larger dark brown blotches present on snout tip and lateral to eyes, and at posterior and lateral disc. Anterior region of first dorsal fin dark greyish-brown; anterior portion of second dorsal fin and upper lobe of caudal fin brown. Large brown blotch at caudal peduncle, and more irregular blotches on lateral aspect of tail underneath both dorsal fins (these blotches more or less continuous with anterior portions of dorsals). Pelvics with dark postero-lateral margins dorsally in some specimens. In large adult female (holotype, MNHN 1996–1555), colouration more uniform dorsally, with fewer blotches and markings (although remnants of blotches remain visible). Preserved specimens have lost most of their original colouration and retained a faint yellowish

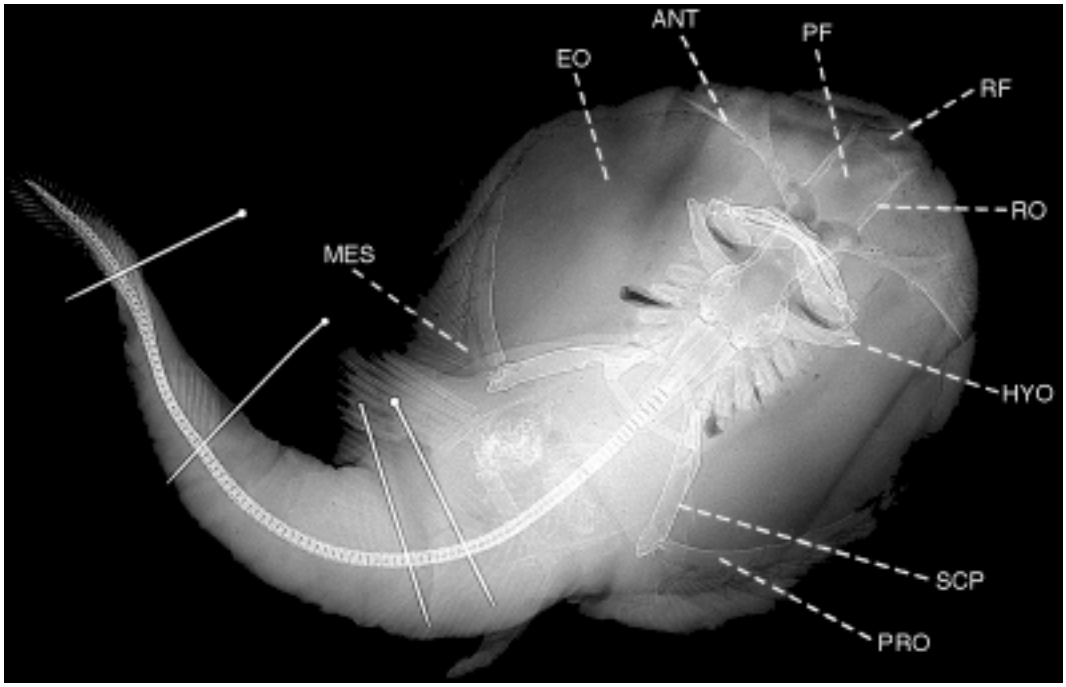

Fig. 5: Radiograph showing skeletal features of *Narcine insolita*, sp. nov. (MNHN 1996–1552, 232 mm *TL*). Abbreviations: ANT – antorbital cartilage; EO – electric organ; HYO – hyomandibula; MES – mesopterygium; PF – precerebral fontanelle; PRO – propterygium; RF – rostral fontanelle; RO – rostrum; SCP – scapulocoracoid

tone with scattered darker spots over disc. Ventral colouration uniform creamy white.

Selected skeletal features — Superficial calcification present throughout, but particularly developed on neurocranium, synarcual, scapulacoracoid and pectoral fin bases. Neurocranium relatively long, occupying just under one-half of disc length, and widest at level of nasal capsules (Fig. 5). Rostrum slender, its length about one-half of neurocranial length. Rostral fontanelle rounded and just wider than long; precerebral fontanelle long, relatively wide and rectangular in outline, with a relatively straight anterior border. Lateral rostral fenestrae present on both sides of rostrum. Branching antorbital cartilages bifurcate at about one-half of their length; small foramina present at bifurcation, and a small posterior projection just mesial to it; antorbitals only weakly calcified. Lateral rostral cartilages absent. Dorsally, the nasal capsules bear small, oblique triangular protuberances. Orbits about one-third of total neurocranial length. Neurocranium with a slight lateral knob-shaped process at the site of articulation with the hyomandibulae (just ventral to it), but unlike in *N. brasiliensis* and *N. bancroftii* the small process is at the anterior portion of the articulation and not mostly posterior to it. Jaws stout, mandibles more robust than palatoquadrates; both sets of jaws separate medially and taper towards the mid-line. Small dorsal projection present on each lower jaw external to articulation with palatoquadrates. Two pairs of triangular labial cartrilages, wider medially towards symphysis. Hyomandibulae stout, especially at base, tapering slightly towards jaw corners, with prespiracular cartilages projecting anteriorly from them. Rectangular palatine cartilages present. Pseudohyoid arch fails to contact neurocranium, situated over the posterior end of the hyomandibulae. Gill arches slender; first and second gill arches, and perhaps third, articulate with the neurocranium posterior to hyomandibulae. Both cerato- and epibranchial elements with central fossae. Fifth ceratobranchial more slender and posteriorly orientated to articulate with scapulocoracoid. Pharyngo-

branchials small, slender and posteriorly oriented, contacting the synarcual distally (only the first three pharyngobranchials visible). Basibranchial copula heart-shaped. Synarcual with four complete centra in its posterior segment, and ten pairs of spinal nerve foramina anterior to first centrum. Triangular lateral stays present just anterior to mid synarcual length, but not sloping anteriorly as much as in *N. brasiliensis* and *N. bancroftii*. Coracoid bar slender; suprascapula articulating tightly to scapular processes. Posterior extension of scapulae stout, with only two condylar facets laterally for pectoral pterygia (one for propterygium and one for meso- plus metapterygium). Scapulae with a large fossa anteriorly. Propterygium divided into at least five segments, the most basal largest and with a sinuous external margin. Pectoral radials divided into at least five unbranched segments. Pelvic girdle slightly arched, with a concave and smooth anterior margin and more irregular posterior aspect. Pre-pelvic processes slender, extending anteriorly to close to scapulocoracoid. Pelvic radials with at least three segments. Basipterygium with a sinuous external margin. Ribs present as of posterior margin of pelvic girdle. Dorsal fins without enlarged basal elements and with segmented radials. Enlarged neural spines present supporting dorsal fins. Dorsal radials of caudal fin originate at caudal origin, but elongated haemal arches originate more anteriorly.

Derivation of name

The specific epithet *insolita* is from *insolitus*, Latin for unusual or uncommon, in reference to the unusual and unique disparate dimensions of the dorsal fins; treated as an adjective. Gender feminine.

Geographical distribution

Known from seven specimens collected at two localities from off the north-west and south-west coasts of Madagascar in 150–175 m water depth (Fig. 6), over predominantly muddy substrata.

DISCUSSION

Comparisons with other species of *Narcine*

N. insolita is readily distinguished from all other species of *Narcine*. The dorsal fins are equal, subequal or the second dorsal fin is greater than the first in all species of *Narcine*, except *N. brevilabiata* Bessednov, 1966, *N. oculifera* Carvalho *et al.* 2002 and two undescribed species (*Narcine* sp. nov. H and *Narcine* sp. nov. I; *sensu* Carvalho 1999). However, in these species the height difference between both dorsal fins is not nearly as great as in *N. insolita*, and both dorsals also have equal or subequal base lengths (in *N. insolita* the second dorsal fin clearly has a shorter base length in all specimens). Additionally, *N. insolita* is easily distinguished from *N. brevilabiata* and *N.* sp. nov. H, because both have upper tooth bands much wider than lower tooth bands, and the tooth bands are subtriangular in outline as opposed to broadly rounded in *N. insolita*. Furthermore, both species, along with *N.* sp. nov. I, are clearly distinct in colouration from *N. insolita*, because all have numerous small (smaller than eye diameter) and somewhat regular dark brown spots over most of the disc and tail regions.

Table III: Comparison of selected morphometric parameters between *Narcine insolita*, sp. nov. and *N. oculifera* (Carvalho 1999, Carvalho *et al.* 2002). See text for explanation of abbreviations

Parameter	Percentage of total length			
	Narcine insolita ($n = 7$)		*Narcine oculifera* ($n = 4$)	
	Range	Mean	Range	Mean
DW	40.4–54.9	48.0	41.9–47.7	44.9
DL	43.5–50.9	47.5	40.5–46.7	43.8
PBS	8.7–11.4	10.2	7.5–9.7	8.7
POS	12.3–15.6	14.2	11.9–13.1	12.7
PNS	9.0–11.6	10.7	8.1–10.0	9.1
ISD	5.2–6.0	5.6	4.5–5.4	4.8

A relatively similar and recently described species of *Narcine* exists in the Gulfs of Oman and Aden (*N. oculifera* Carvalho *et al*. 2002; referred to as "*Narcine* sp. nov. D" in Carvalho 1999). *N. insolita* shares with *N. oculifera* the unique arrangement of large, bulging eyes and rounded spiracles with elevated rims, a much greater interorbital distance compared to interspiracular distance, individual teeth with rounded and small lateral cusplets, a very enlarged first dorsal fin, as well as aspects of the dorsal colour pattern. The most distinguishing characteristic separating both species is the shape and size of the dorsal fins: in *N. insolita*, the first dorsal fin is much taller and broader than the second, with a greater free posterior lobe (implying that the base of the first dorsal fin is markedly greater than the base of the second), and *N. insolita* also has a more broadly rounded first dorsal fin apex compared to *N. oculifera*. In *N. oculifera*, both dorsal fins are relatively similar in size (the first dorsal fin is only

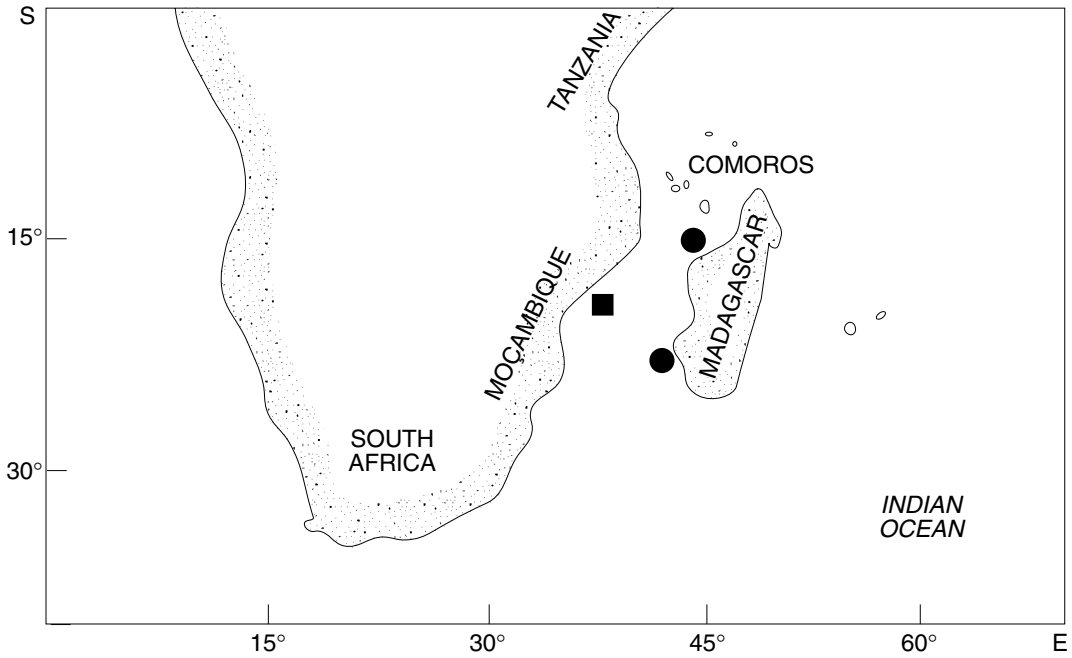

Fig. 6: Map of the south-western Indian Ocean showing distribution of *Narcine insolita*, sp. nov., as closed circles off Madagascar (holotype is from locality to the north), and *Narcine* sp. (square off Moçambique)

slightly more prominent than the second) and the length of both fin bases is about equal. The differences between both dorsal fins in these species are not dependent on size or sex of specimens, because they are apparent even in the smallest specimens examined and among males and females of both species.

It is not the intention to provide here too much information concerning *N. oculifera* from the Gulfs of Oman and Aden; however, *N. insolita* is further distinguished from it by having more precaudal vertebrae (ranging from 68 to 71, but only two of seven specimens have below less than 70, v. 64–68, only one specimen with 68 respectively), which is also reflected in the total number of vertebral centra (119–127 v. 109–119 respectively). Certain other proportional differences, although not as evident or as reliable, may further help to distinguish both species (Table III; see also Carvalho 1999, Carvalho *et al.* 2002).

In addition to the features described above, males of *N. oculifera* achieve sexual maturity at a smaller size than those of *N. insolita*, providing further evidence for their separation. Specimen CAS 58368 from Oman (*N. oculifera*) has fairly firm claspers at 240 mm *TL* (with a clasper length of 31.2 mm), whereas MNHN 1996–1554 from Mada-gascar (*N. insolita*; Fig. 2) has claspers much less firm at 266 mm *TL* (with a clasper length of 34.1 mm). Another adult male from the Gulf of Aden (*N. oculifera*) had firm claspers 31.1 mm long at 291 mm *TL*. *N. insolita* and *N. oculifera* appear to be monophyletic, forming a species-pair (Carvalho 1999).

Narcine insolita cannot be confused with the other described species of *Narcine* from the south-western Indian Ocean, *N. rierai* (Lloris and Rucabado 1991, Compagno 1995), because the latter species is unique within the genus in having a longer-than-wide nasal curtain (Carvalho 1999). Many other features allow for a straightforward separation of both species, including colouration (uniform brown to reddish-brown in *N. rierai*), dorsal fins (of more or less equal dimensions in *N. rierai*), ridge-like lateral tail fold and spiracles without elevated rims in *N. rierai*, and many proportional measurements of tail and disc (Carvalho 1999). *N. rierai* occurs along the continental slope of eastern Africa from Somalia to Moçambique and possibly to South Africa, but has not been collected from Mada-gascar.

Carvalho (1999) included a specimen from Moçam-

bique, first reported by Compagno (1995), in "*Narcine* sp. nov. E" (= *N. insolita*). This was done on the basis of their many superficial similarities and geographical proximity, and without specific measurements of the dorsal fins of the Moçambique specimen. More detailed comparisons involving all material from Madagascar (type-series of *N. insolita*) and the Moçambique specimen, particularly in relation to dorsal fin proportions, reveal that they are not conspecific. The Moçambique specimen is briefly described below as *Narcine* sp., where it is further compared to *N. insolita*.

Comparison with *Narcine* sp. from Moçambique

Narcine sp. — Compagno (1995): vi-vii, Fig. 24a.2 (brief diagnosis, outline illustration; Moçambique).
Narcine sp. nov. E: Carvalho (1999): 243–250, Figs 88–90 (in part; diagnosis, description, distribution, colour photographs; Moçambique).

MATERIAL

SAM 34812, pre-adult female, 216 mm *TL*, 18°30´S, 37°15´E, depth 69 m, R.V. *Algoa*, Sta. COO 830-014-027-2022 (Moçambique) (Fig. 7).

DESCRIPTION

External morphology — Disc oval or heart-shaped, just longer than wide and with a broadly angled anterior contour; disc widest just posterior to its mid-length, without prominent lobes posteriorly where it adjoins tail; disc overlaps origin of pelvic fins only slightly. Preocular snout length about one-fourth of disc length. Eyes large and bulging, eye-diameter just over one-half of interorbital distance. Spiracles very large and circular, with smooth elevated rims all around. Spiracles do not extend anteriorly beyond posterior margins of eyes. Interspiracular distance smaller than interorbital distance; eyes and spiracles close together. Nasal curtain relatively short, much wider than long and with a somewhat pronounced bulging lobe at centre. External tooth bands broadly circular; upper tooth band slightly wider than lower tooth band. Outer corners of mouth more or less on same vertical level as external margins of nostrils. Electric organs more discernible on ventral surface, extending from level of nostrils to about posterior one-seventh of disc length. Gill slits relatively wide; distance between fifth gill slits clearly smaller than distance between first gill slits.

Pelvic fins wider than long (when measured together), with slightly thickened and angular apices. Tail stout at base, not tapering greatly towards caudal fin; tail length greater than disc length, as measured from anterior aspect of pelvic fins. First dorsal fin origin, and most of first dorsal fin base, anterior to posterior margin of pelvic fin. Dorsal fins similar in shape and size, but second dorsal just taller than first and with a longer base (*HFD* 19 mm; *LFD* 19 mm; *HSD* 20 mm; *LSD* 20 mm). Both dorsal fins broadly rounded posteriorly and at apex, and with a relatively large free posterior lobe. Caudal short but somewhat tall, and broadly rounded posteriorly. Lateral tail folds wide, flap-like, extending from underneath level of first dorsal fin to caudal base. Interdorsal distance more or less equal to distance between second dorsal and caudal fin.

Colouration — Dorsal colouration in freshly collected specimen similar to preserved specimens of *N. insolita*, with a yellowish-brown background and darker brown blotches over antero-lateral margins of disc, at anterior snout region, posteriorly on disc, over mid-disc region and interorbital space. More faded blotches present on mid-disc region. Faint remnants of a reticulated pattern may be present on anterior snout region and laterally to eyes. Darker blotches present on dorsal tail region, anterior half of both dorsal fins (extending ventrally to lateral aspect of tail), and over much of caudal fin, especially at caudal apex. Faint dark brown blotch present on interdorsal region and on posterior margins of pelvic fins. Uniform creamy white ventrally.

REMARKS

The specimen from Moçambique (SAM 34812) differs morphologically from the Madagascar specimens, currently prohibiting its inclusion in *N. insolita*. Its second dorsal fin is very close in dimensions and extent of the free posterior lobe to the first dorsal fin, and is in fact slightly larger than the first dorsal fin (see dimensions given above; Fig. 7). There is also a small posterior projection of the joint nasal curtain at its mid-width, which is lacking in specimens of *N. insolita* from Madagascar. The specimen from Moçambique is a female, probably pre-adult (216 mm *TL*), and differs in these respects from the pre-adult female of similar size from Madagascar (MNHN 1996–1552, 232 mm *TL*), as well as from the adult female from Madagascar (holotype, MNHN 1996–1555, 356 mm *TL*). Both of these specimens clearly have a much larger first dorsal fin (in both height and length of base) compared to the second dorsal fin, and lack the central lobe of the joint nasal curtain.

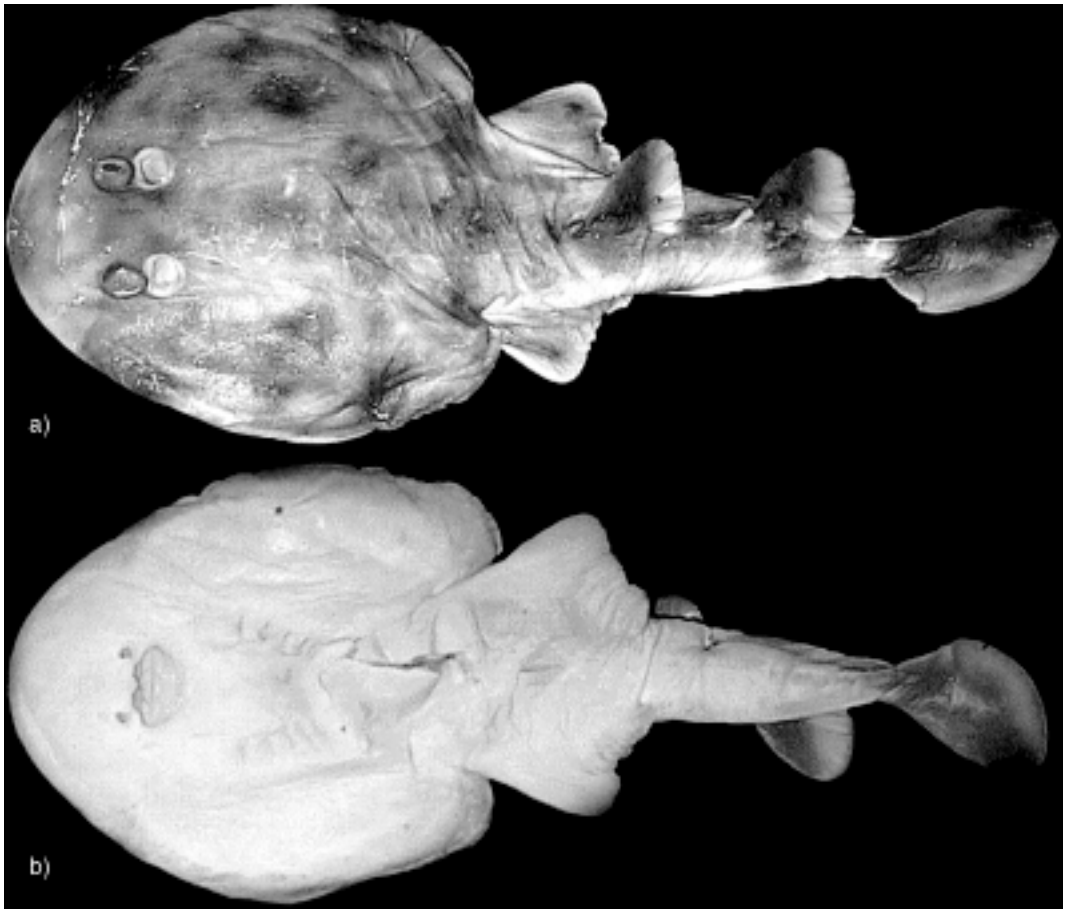

Fig. 7: *Narcine* sp. from Moçambique (SAM 34812, 216 mm *TL*) in (a) dorsal and (b) ventral views. Note that the caudal fin is pointing downwards in (b)

More specimens from Moçambique are needed to further evaluate the systematic relevance of these distinctions, but two other options regarding its identification are possible: it may represent an additional undescribed species from the Moçambique Channel, or it may be conspecific with the recently described species of *Narcine* from the Gulfs of Oman and Aden (*N. oculifera* Carvalho *et al.* 2002). In this latter species, both dorsal fins are more similar in dimensions, even though they are relatively quite large (see discussion above concerning *N. oculifera*). However, the first dorsal fin is also larger than the second in *N. oculifera* (albeit by much less than in *N. insolita*), even though they are both subequal in base length. Furthermore, the nasal curtain in *N. oculifera* also has a straight posterior margin without the central lobe present in the Moçambique specimen. It is therefore tentatively concluded that the Moçambique specimen represents another undescribed species of *Narcine* from the southwestern Indian Ocean, but the collection of more specimens is necessary for a formal description.

Underwater photographs taken off the Comoros Islands by Prof. Hans Fricke (Max-Planck Institute, Seewiesen) reveal the presence of what appears to be a specimen of *Narcine* that is perhaps similar to the specimen from Moçambique. The photographs do not provide much morphological detail, but the dorsal fins seem to be of subequal size (a more precise comparison regarding size of the dorsal fins is not possible). Other similarities in colouration, general

disc shape and tail proportions indicate that the species in the Moçambique Channel may range slightly farther north, but this comparison must await the collection of material from the Comoros Islands.

Sexual maturity of *N. insolita*

Size at sexual maturity is not precisely known for female specimens of *N. insolita* (males probably mature at close to or >270 mm *TL*; see discussion above concerning the separation of *N. insolita* from *N. oculifera*). The holotype is the largest female (and specimen) examined at 356 mm *TL*, and was sexually mature. Brief dissection of its visceral cavity revealed the presence of compacted eggs (without recognizable embryos) in the left uterus only, and most likely only one uterus is functional at a given time. The walls of the uterus are extremely thin-walled, semi-transparent, and apparently have no nutrient-supplying function. This large specimen is slightly deformed from its original shape because of preservation, being laterally dislocated posterior to the disc at the tail base, but it is nonetheless chosen as the holotype because it is the only unequivocally known adult specimen.

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