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Two new species of bamboo sharks (Orectolobiformes: Hemiscylliidae) from Western New Guinea

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Abstract

Two new species of hemiscylliid sharks are described from the Bird's Head region of western New Guinea (Papua Barat Province, Indonesia). They differ from congeners on the basis of both colour patterns and DNA composition. *Hemiscyllium galei* is described from two specimens, 542.5-567.5 mm TL, collected at Cenderawasih Bay. The species is similar in appearance to *H. freycineti*, reported from areas immediately westward including the Raja Ampat Islands. The new species differs from *H. freycineti* in possessing white lines and spots along the margin of the large, dark dorsal saddles as well as scattered white spots, mainly on the upper side. In addition, *H. galei* is characterised by a row of about seven well-defined, horizontally-ovate, dark spots on the lower side between the abdomen and caudal-fin base. *Hemiscyllium henryi* is described from three specimens, 564.0-815.0 mm TL, collected in the vicinity of Triton Bay. It is most similar in general appearance to *H. ocellatum* from northern Australia, but differs in the structure of the post-cephalic ocellus (usually a pair of merged "twin-ocelli" with a poorly defined white halo) and possesses well-defined dark brown saddles/bars along the back and dorsal margin of the caudal fin as well as a dark spot at the origin of the pectoral and pelvic fins. A final difference concerns the presence of numerous small brown spots on the dorsal fins of *H. ocellatum*, in contrast to the mainly spotless pattern on the dorsal fins of *H. henryi*.

Zusammenfassung

Beschrieben werden zwei neue Arten der Hemiscylliiden-Haie aus der Gegend von Bird's Head vor dem westlichen Neuguinea (Provinz Papua Barat, Indonesien). Von den anderen Angehörigen der Gattung lassen sie sich durch Farbmerkmale und DNS-Zusammensetzung unterscheiden. *Hemiscyllium galei* wird auf der Grundlage von zwei Exemplaren mit 542,5-567,5 mm TL (Gesamtlänge) beschrieben, die an der Cenderawasih-Bucht gefangen wurden. Die Art ähnelt im Erscheinungsbild *H. freycineti*, deren Exemplare in einem Gebiet beobachtet wurden, das sich westlich anschließt und bis zu den Raja-Ampat-Inseln reicht. Die neue Art unterscheidet sich aber durch weiße Linien und Flecken am Rand des großen dunklen Rückensattels sowie durch verstreute weiße Flecken hauptsächlich auf der Oberseite. Außerdem ist *H. galei* durch eine Reihe sieben klar begrenzter horizontal-ovaler dunkler Flecken gekennzeichnet, die sich auf der Unterseite zwischen Abdomen und Schwanzflossen-Basis erstrecken. *Hemiscyllium henryi* wird anhand von drei Exemplaren mit 564,0-815,0 mm Gesamtlänge (TL) beschrieben, die in der Nähe der Triton-Bucht gesammelt wurden. Sein Erscheinungsbild ähnelt stark *H. ocellatum* von Nord-Australien, unterscheidet sich aber durch die Struktur der hinter dem Kopf sichtbaren "Augenflecken" (normalerweise ein verschmolzenes Paar von "Zwillingsflecken" mit undeutlichem weißen Ring) und zeigt außerdem klar begrenzte dunkelbraune sattel- oder streifenförmige Flecken am Rücken entlang und am dorsalen Rand der Schwanzflosse sowie einen dunklen Fleck am Ursprung der Brust- und der Bauchflossen. Schließlich unterscheidet sich *H. ocellatum* durch zahlreiche kleine braune Flecken an den Rückenflossen im Gegensatz zu der fast fleckenlosen Farbgebung an den Rückenflossen bei *H. henryi*.

Résumé

Deux nouvelles exoèces de requins hémiscylliidés sont décrites, originaires de la région du Vogelkop, Nouvelle-Guinée occidentale (Province de Papua Barat, Indonésie). Ils se distinguent de leurs congénères à la fois par le patron de coloration et la composition de l'ADN. *Hemiscyllium galei* est décrit sur base de deux spécimens, de 542.5-567.5 mm de LT, collectés à Cenderawasih Bay. L'espèce est similaire à *H. freycineti*, signalé dans des régions immédiatement à l'ouest, incluant les îles Raja Ampat. La nouvelle espèce se distingue de *H. freycineti* par des lignes et des taches blanches en bordure des grandes selles dorsales sombres ainsi que par des taches blanches disséminées, sourtout sur la partie supérieure. En outre, *H. galei* se caractérise par une rangée d'environ sept taches sombres bien nettes, horizontalement ovales sur la partie inférieure, entre l'abdomen et la base de la caudale. *Hemiscyllium henryi* est décrit sur base de trois spécimens, de 564.0 à 815.0 mm de LT, collectés aux environs de Triton Bay. Son apparence générale évoque le plus *H. ocellatum*, du nord de l'Australie, mais se distingue par la

structure de l'ocelle postcéphalique (généralement une paire d'ocelles jumelés avec un halo blanc plus marqué) et il possède des barres en selle brun foncé et bien nettes le long du dos et du lobe dorsal de la caudale, ainsi qu'une tache obscure à la naissance des pectorales et de pelviennes. Une dernière différence concerne la présence de nombreuses petites taches brunes sur les dorsales de *H. ocellatum*, alors que le dorsales de *H. henryi* en sont pratiquement dépourvues.

Sommario

Si descrivono due nuove specie di squali hemiscillidi dalla regione di Bird's Head della Nuova Guinea occidentale (provincia di Papua Barat, Indonesia). Esse differiscono dai congeneri sia per la colorazione sia per la composizione del DNA. *Hemiscyllium galei* è descritto sulla base di due esemplari di 542.5-567.5 mm TL raccolti nella baia di Cenderawasih. La specie è superficialmente simile a *H. freycineti*, che abita le vicine aree ad occidente incluse le isole di Raja Ampat. La nuova specie differisce da *H. freycineti* nell'avere linee e macchie bianche lungo il margine delle larghe selle dorsali scure e anche per macchie bianche disperse, principalmente sul lato superiore. In aggiunta, *H. galei* è caratterizzato da una fila di circa sette ben definite macchie scure di forma ovoidale sul lato inferiore tra l'addome e la base della pinna caudale. *Hemiscyllium henryi* è descritto sulla base di tre esemplari di 564.0-815.0 mm TL raccolti nelle vicinanze della baia del Tritone. La specie più simile nell'aspetto generale è *H. ocellatum* dell'Australia settentrionale, ma se ne discosta per la struttura dell'ocello post-cefalico (di solito una coppia di "ocelli gemelli" fusi tra loro circondati da un alone bianco poco definito) e poiché possiede ben definite barre o selle brune lungo il dorso e il margine dorsale della pinna caudale e una macchia scura all'origine della pinna pettorale e delle pinne pelviche. Un'altra differenza è la presenza di numerose piccole macchie brune sulle pinne dorsali di *H. ocellatum*, mentre le pinne dorsali di *H. henryi* ne sono sostanzialmente prive.

INTRODUCTION

The bamboo sharks of the genus *Hemiscyllium* Müller & Henle, 1837 are confined to shallow coral reefs of northern Australia and New Guinea. They are small (to about 100 cm TL), relatively sedentary, nocturnal sharks that appear to lack efficient dispersal capabilities; hence most of the known species exhibit relatively limited regional distributions. They are generally active at night, foraging on benthic invertebrates and small fishes. During the day they typically seek shelter under large rocks, coral formations, or under ledges. The genus was revised by Dingerkus & DeFino (1983), who recognised five species. More recent coverage includes reviews by Compagno & Niem (1998), and Compagno (2001). In addition, the two Australian species were diagnosed and illustrated by Last & Stevens (1994).

Our knowledge of species from New Guinea is poor and based on relatively few specimens. Four species are generally recognised in current literature (e.g. Compagno, 2001): *H. freycineti* (Cuvier, 1824), *H. hallstromi* Whitley, 1967, *H. ocellatum* (Bonnaterre, 1788), and *H. strahani* Whitley, 1967. An additional species, *H. trispeculare* Richardson, 1843, occurs in northern Australia. Although *H. ocellatum* was reported from the entire coast of New Guinea, as well as the Solomon Islands, Malaysia and Sumatra, it is apparently restricted to Australia. The extra-limital records are apparently based on misidentifications. Similarly, distribution maps for *H. freycineti* in Compagno & Niem (1998) and Compagno (2001) indicate a circum-New Guinea range. However, according to Allen (unpublished data) it is restricted to the far-western part of New Guinea and a similar-patterned shark from eastern Papua New Guinea previously identified as *H. freycineti* represents an undescribed taxon (*Hemiscyllium* species in key below).

The present paper describes two new *Hemiscyllium* that we collected in 2006 and 2007 during separate Conservation International marine biological surveys of Cenderawasih Bay and Triton Bay. Although the two bays are only 115 km apart, they are separated by the New Guinea mainland, which in this region forms a narrow isthmus between the Bird's Head Peninsula to the west and main portion of New Guinea to the east (Fig. 1).

MATERIALS AND METHODS

Type specimens are deposited at Pusat Penelitian dan Pengembangan Oseanologi, Jakarta, Indonesia (NCIP), the United States National Museum of Natural History, Washington, D.C. (USNM), and the Western Australian Museum, Perth (WAM).

Proportional measurements and counts of vertebral centra in the descriptions are given first for the holotype followed by the value(s) for the paratype(s) if different. Technical terms and measurements follow those explained and illustrated by Compagno (1984) and Dingerkus & DeFino (1983) except the term "nose" of the latter authors has been replaced here with snout tip. Terms which require clarification include the head length, which is measured from the tip of the snout to the origin of the pectoral fin, snout length, which is the distance between the snout tip and anterior edge of the eye, and preanal body depth, which is measured at the level of the anal-fin origin. Total length

(TL) is the distance from the snout to the caudal-fin tip.

The tip of the caudal fin of the paratype of *H. galei* is missing. Extrapolation from the holotype and other similar-sized hemiscyllids revealed that the missing section is approximately 40 mm in length. Therefore, the total length of the paratype was increased from 542.5 to 582.0 in order to facilitate the comparison of morphometric proportions.

Tissue samples for DNA analysis were obtained from the two new taxa and the sister taxa *H. freycineti* and *H ocellatum* and sent to Christine Dudgeon, a geneticist from Queensland University, who has done prior work (unpublished) on the phylogeny of *H. ocellatum* from eastern Australia. Total genomic DNA was extracted from 25 mg of fin tissue using the DNeasy Tissue Extraction Kit (Qiagen) following the instructions of the supplier. A fragment including partial mitochondrial NADH Dehydrogenase subunit 4 gene (ND4), tRNA-His and tRNA-Ser genes was amplified through polymerase chain reaction (PCR) using the primers: ND4-F: 5' – CACCTATGACTAC-CAAAAGCTCATGTAGAAGC - 3' (Arevalo et al. 1994) and H12293-Leu-R: 5' – TTGCACCAA-GAGTTTTTGGTTCCTAAGACC - 3' (Inoue et al. 2001). Reactions were conducted in 30 μl total amounts and consisted of: 10 μM each primer, 400 μM of each dNTP, 3 units *Taq* polymerase, 1 x PCR Buffer (Qiagen) and 30-50 ng extracted DNA. PCRs were conducted on 9700 Perkin Elmer thermocyclers and consisted of an initial denaturation step at 95°C for 5 min, followed by 30 cycles of 95°C for 15 sec, 56°C for 30 sec and

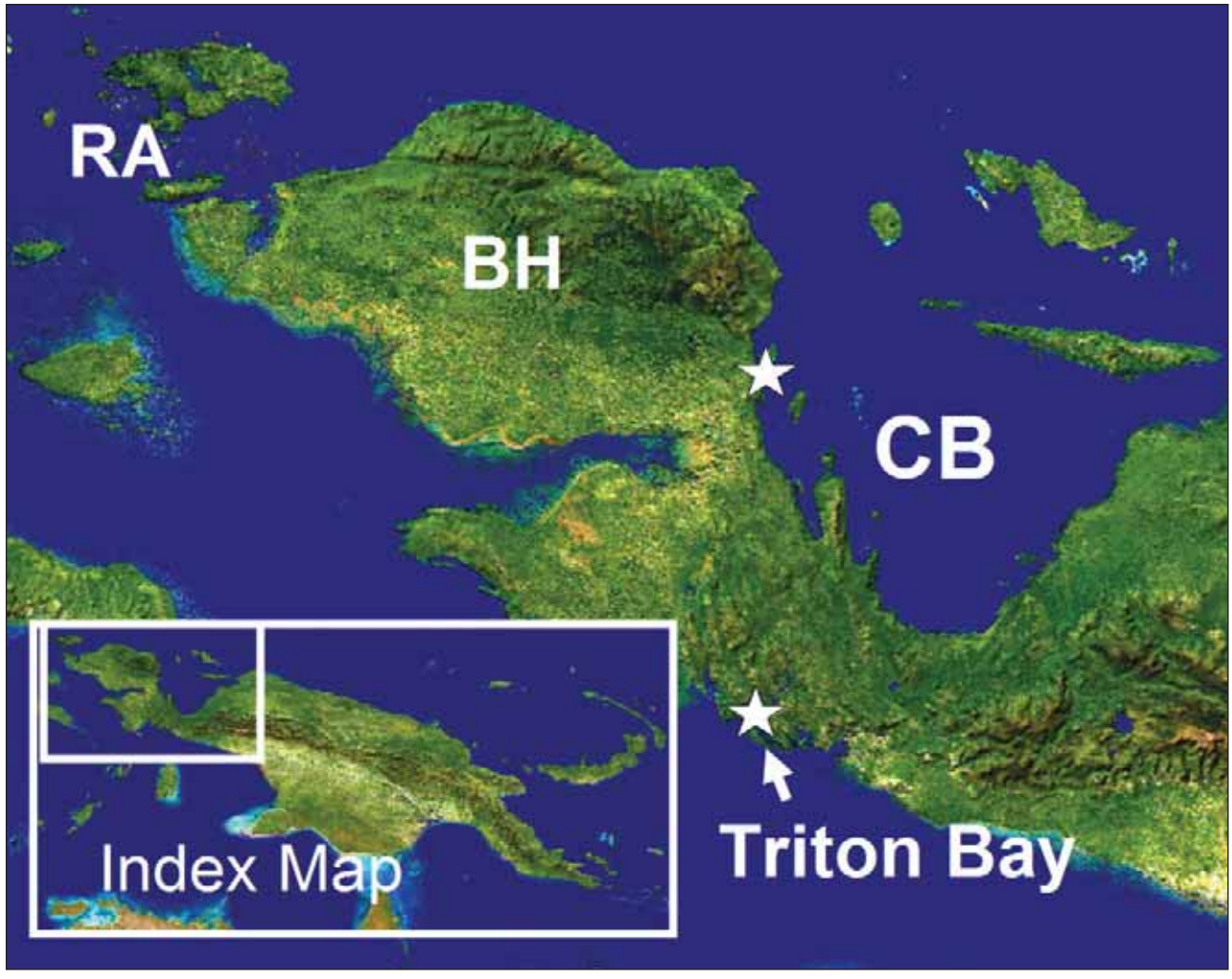

Fig. 1. Map of western New Guinea (Papua Barat Province, Indonesia) showing collection locations (star symbols) of new species of *Hemiscyllium*. Abbreviations as follows: BH = Bird's Head Peninsula, CB = Cenderawasih Bay, and RA = Raja Ampat Islands. NASA satellite images.

72°C for 1 min, and a final extension at 72°C for 7 min. The PCR products were cleaned using QIAquick PCR Purification Kit (Qiagen). Sequences were conducted in the forward direction using Big Dye Terminator v3.1 Cycle Sequencing Kit (Applied Biosystems) following manufacturer's instructions. Sequencing products were precipitated by adding 4 μL sodium acetate (3 M, pH 5.2) and 50 μL 100% ethanol and centrifuged for 30 min at 13000 rpm. The pellet was washed twice with 500 μL 70% ethanol and then products resolved on a 3730xl Genetic Analyser (Applied Biosystems).

Sequences were aligned using Sequencher software (GeneCodes). The program Modeltest version 3.7 (Posada & Crandall 1998) was used to assess the best-fit model for the nucleotide substitution. The hierarchical likelihood ratio test ranked the TrN + G substitution model (gamma distribution = 0.3674) as having the best fit to the data. The Tamura-Nei (Tamura & Nei 1993) substitution model accounts for variable base frequencies, transition rates and rate variation among sites. Akaike's Information Criterion ranked the TrN + I model as having best fit which is also the Tamura-Nei model, but includes invariable sites and no rate variation among sites. Phylogenetic trees were constructed in PAUP version 4.0b (Swofford 1998) using both models. Maximum likelihood, maximum parsimony and neighbour-joining trees were constructed with a specimen of *Chiloscyllium punctatum* as the outgroup taxon. Confidence in tree topology was evaluated by bootstrapping across 1000 bootstrap replicates (Felsenstein 1985). Pairwise distances within and between putative taxa were calculated using the TrN + G model implemented in Mega version 3.1 (Kumar et al. 2004).

Hemiscyllium galei n. sp.

(Figs 2-6; Tables I-III)

Holotype: NCIP 6324, male, 567.5 mm TL, reef near Rumberpon Village, 03°53.757'S 134°06.638'E, western Cenderawasih Bay, Papua Barat Province, Indonesia, 3-4 m, collected by hand, M. and A. Erdmann, 19 February 2007.

Paratype: WAM P.32888-001, male, 542.5 mm TL, collected with holotype.

Diagnosis: A species of bamboo shark belonging

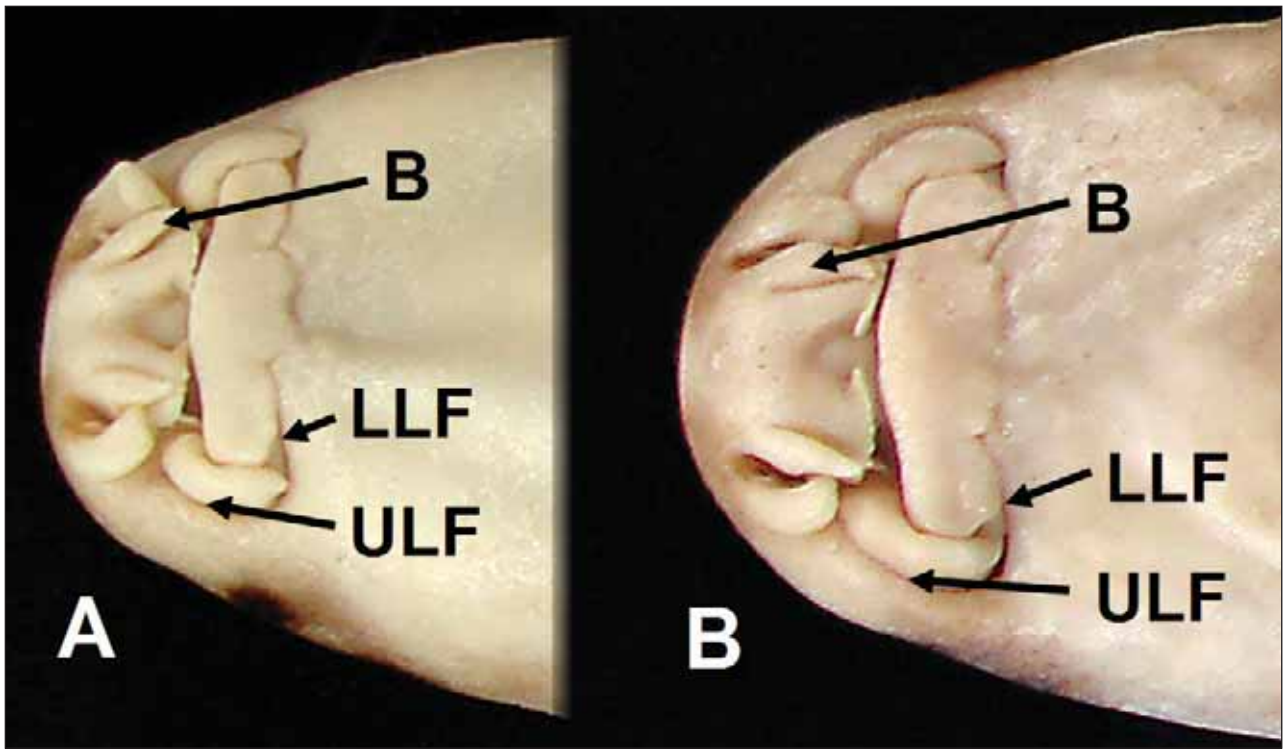

Fig. 2. Ventral view of heads of *Hemiscyllium galei* (A), holotype, 567.5 mm TL, Cenderawasih Bay, Papua Barat Province, Indonesia, and *Hemiscyllium henryi* (B), paratype, 564.0 mm TL, Triton Bay, Papua Barat Province, Indonesia. Abbreviations as follows: ULF = upper labial fold, LLF = lower labial fold, and B = barbel. Photos by G. R. Allen.

Table I. Morphometric proportions for type specimens of *Hemiscyllium galei* and *H. henryi* expressed as percentage of the TL.

	H. henryi		*H. galei*		
Character	Holotype NCIP 6324	Paratype WAM P.32888	Holotype NCIP 6323	Paratype USNM 390771	Paratype WAM P.32889
Sex	male	male	male	female	male
Total length	567.5	582.0	783.0	815.0	564.0
Precaudal length	76.8	82.7	82.8	83.9	75.5
Head length	12.7	13.8	13.4	13.7	13.7
Head width	8.8	7.5	9.7	9.8	8.5
Head depth	7.8	8.6	7.9	8.2	7.3
Preanal body depth	3.5	3.6	3.8	3.8	3.9
Snout to first gill slit	11.7	12.1	10.7	11.4	11.2
First to fifth gill slit	4.3	4.8	4.9	5.2	4.8
First gill-slit height	1.4	1.2	1.5	1.9	1.5
Fifth gill-slit height	2.6	1.8	2.2	2.6	2.2
Eye diameter (horizontal)	1.7	1.8	1.7	1.6	1.5
Eye diameter (vertical)	1.0	0.7	0.6	0.7	0.6
Fleshy interorbital width	4.8	4.2	4.7	4.0	4.4
Bony Interorbital width	3.4	3.2	3.3	3.2	3.4
Snout to eye	6.2	6.2	5.0	6.0	5.5
Snout to spiracle	11.9	7.1	6.6	6.9	6.2
Snout to mouth	2.6	2.5	2.2	2.0	2.0
Lower labial furrow length	0.9	0.9	1.1	1.2	1.1
Lower labial flap width	1.3	1.4	1.5	1.0	1.3
Postoral fold	1.8	1.7	1.8	1.5	1.8
Mouth width	5.1	4.8	5.1	4.9	4.3
Barbel length	1.1	1.4	1.7	1.5	1.6
Snout to first dorsal fin	37.4	37.2	40.4	36.8	38.1
Snout to pelvic fin origin	27.8	28.0	27.5	30.1	28.7
Snout to vent	29.7	30.2	30.3	31.3	31.6
Vent to anal fin	40.5	41.6	44.1	42.3	41.7
Vent to caudal-fin tip	68.9	69.6	69.3	66.7	69.9
Interdorsal width	11.9	11.2	13.7	13.3	12.9
Pectoral-fin length	11.0	11.6	11.2	11.0	11.5
Pelvic-fin length	11.5	11.2	10.5	10.2	9.9
First dorsal-fin base	8.4	9.3	7.7	7.1	6.9
First dorsal-fin height	6.7	7.2	8.2	9.1	10.1
Free margin of first dorsal fin	5.2	3.7	4.9	4.2	4.3
Second dorsal-fin base	8.1	7.7	8.3	7.0	8.0
Second dorsal-fin height	7.2	7.5	7.8	7.0	8.0
Free margin of second dorsal fin	3.3	2.4	4.1	3.8	3.5
Anal-fin base	8.8	9.8	9.1	9.8	9.0
Anal-fin height	2.9	2.9	3.2	3.3	3.0
Free margin of anal fin	1.5	1.7	2.0	1.5	1.8
Subcaudal length	17.3	damaged	17.2	17.7	17.4
Clasper length (inner)	11.1	10.3	10.7	–	4.9
Clasper length (outer)	6.3	6.6	7.4	–	1.4

to the genus *Hemiscyllium*, distinguished by its unique colour pattern, particularly the combination of white lines/spots along the margin of the large, dark saddles on the back, scattered white spots (mainly on upper side), and a row of 7-8 well-defined, horizontally-ovate, dark spots on the lower side between the abdomen and caudal-fin base.

Description: Vertebral centra 195 (160, but end of caudal fin missing); body and tail relatively slender, tapering posteriorly; precaudal length 1.2, head length 7.9 (7.2), both in TL; maximum depth of head (at pectoral fin origin) about equal to width of head at level of eye; horizontal eye diameter 3.6 (3.5) in snout length, the vertical diameter 1.8 (2.5) in horizontal diameter; fleshy interorbital width 1.3 (1.5), bony interorbital width 1.8 (1.9), both in snout length; snout blunt and short, snout

tip to eye 2.0 (2.2), snout tip to mouth 2.4 (2.5), snout tip to spiracle 1.1 (1.9), snout tip to first gill slit 3.0 (2.9), all in head length; gill slits on rear part of head, above to slightly anterior of pectoral-fin base; distance between first and fifth gill slit 3.0 (2.9) in head length; height of gill slits gradually increasing posteriorly, the first 4.4 (5.2) and fifth 2.4 (3.5), both in snout length.

Mouth small and transverse, positioned well forward on ventral surface of head (Fig. 2B), its width 1.2 (1.3) in snout length; short barbel on each side of ventral snout, its length 5.5 (4.5) in snout length; maximum width of lower labial flap 4.8 (4.6), length of postoral fold (upper labial furrow) 3.4 (3.6), length of lower labial furrow 6.7 (6.6), all in snout length; teeth pavement-like, composed of numerous rows; individual teeth broad-based with singe posteriorly-directed spike-like projection, the spikes of innermost rows more developed.

Snout tip to first dorsal-fin origin 2.7, snout tip to pelvic-fin origin 3.6, snout tip to vent 3.4 (3.3), vent to anal fin origin 2.5 (2.4), vent to tail tip 1.5 (1.4), all in TL. Pectoral fins below gill openings, their length 1.2 in TL; pelvic fins immediately anterior to vertical line passing through first dorsal fin origin, their length 1.1 (1.2) in TL; dorsal fins positioned well back on body, about equal in height; first dorsal-fin base 1.5 in head length, first dorsal-fin height 1.3 in first dorsal-fin base; free margin of first dorsal fin 1.7 (1.9) in first dorsal-fin height; interdorsal distance 1.1 (1.2) in head length; second dorsal-fin base 1.6 (1.8) in head length; second dorsal-fin height 1.1 (1.0) in second dorsal-fin base; free margin of second dorsal fin 2.2 (3.1) in second dorsal-fin height; a long and low anal fin just anterior to caudal fin; anal-fin base 1.4 in head length, anal-fin height 3.1(3.3) in anal-fin base; free margin of anal fin 1.9 (1.8) in anal-fin height; an elongated and thick precaudal tail, its depth at level of anal-fin origin 3.7 (3.9) in head length; subcaudal length 5.8 in TL.

Male clasper stout and elongate, about same length as pelvic fins, inner length 1.1 (1.3), outer length 2.0 (2.1), both in head length; clasper width at base 3.3 (3.3), in outer length of clasper.

Colour in life (Fig. 3 upper and Fig. 4. lower): generally pale reddish-brown (fawn), white on ventral surface, with relatively large, dark-brown, post-cephalic ocellus usually poorly defined) on middle of side and dark brown bar (composed of several merged spots), immediately

Fig. 3. Underwater photograph of *Hemiscyllium galei* (upper), approximately 650 mm TL, Cenderawasih Bay and *H. freycineti* (lower), approximately 650 mm TL, Raja Ampat Islands. Photos by G. R. Allen.

Table II. Comparison of mean values for selected proportional measurements (as percentage of TL) of species of *Hemiscyllium*. Data for *H. galei* and *H. henryi* were obtained from the current study, but all others except *H. freycineti* are from Dingerkus & DeFino (1983). The data for *H. freycineti* were taken by the authors from type specimens at MNHN.

	H. freycineti	*H. galei*	*H. hallstromi*	*H. henryi*	*H. ocellatum*	*Hemiscyllium* sp.	*H. strahani*	*H. trispeculare*
Number specimens	3	2	9	3	20	6	2	7
Snout to first dorsal fin	36.02	37.28	35.98	38.43	36.18	37.99	36.96	36.13
Snout to pelvic fin	28.01	27.91	25.93	28.75	28.58	28.62	28.63	29.39
Snout to vent	30.13	29.94	30.07	31.04	30.32	29.52	29.36	31.51
Vent to anal fin	45.34	41.05	42.67	42.69	43.11	43.87	43.82	39.96
Vent to tail tip	69.15	69.24	68.59	68.55	68.37	69.62	68.67	67.26
Interdorsal distance	13.39	11.56	12.06	13.29	12.48	13.02	12.33	11.60
Pelvic-fin length	9.95	11.35	9.70	10.20	9.59	9.69	10.19	10.50
First dorsal-fin base	7.69	8.88	8.64	7.23	8.39	7.00	7.67	8.90
First dorsal-fin height	6.36	6.94	6.97	9.12	6.48	7.20	6.92	8.42
Second dorsal-fin base	8.24	7.92	7.79	7.76	7.81	7.24	7.65	7.67
Second dorsal-fin height	6.02	7.36	6.55	7.59	6.45	6.53	6.31	7.65
Anal-fin base	8.00	9.31	9.02	9.31	9.02	7.77	9.17	10.25
Anal-fin height	3.10	2.90	2.33	3.17	2.28	2.08	2.66	2.91

behind (Fig. 5); three, progressively smaller dark brown saddles across back from rear edge of head to dorsal-fin base, a similar saddle between dorsal fins, and four additional dark saddles on dorsal edge of tail; the four large saddles on body outlined with large brown spots, darker than surrounding spots; each saddle with white anterior and posterior margins; also, an irregular matrix of white spots on side of body; head and body covered with relatively dense network of round to polygon-shaped brown spots, those on dorsal surface of head smaller than eye, numbering about 25 (only

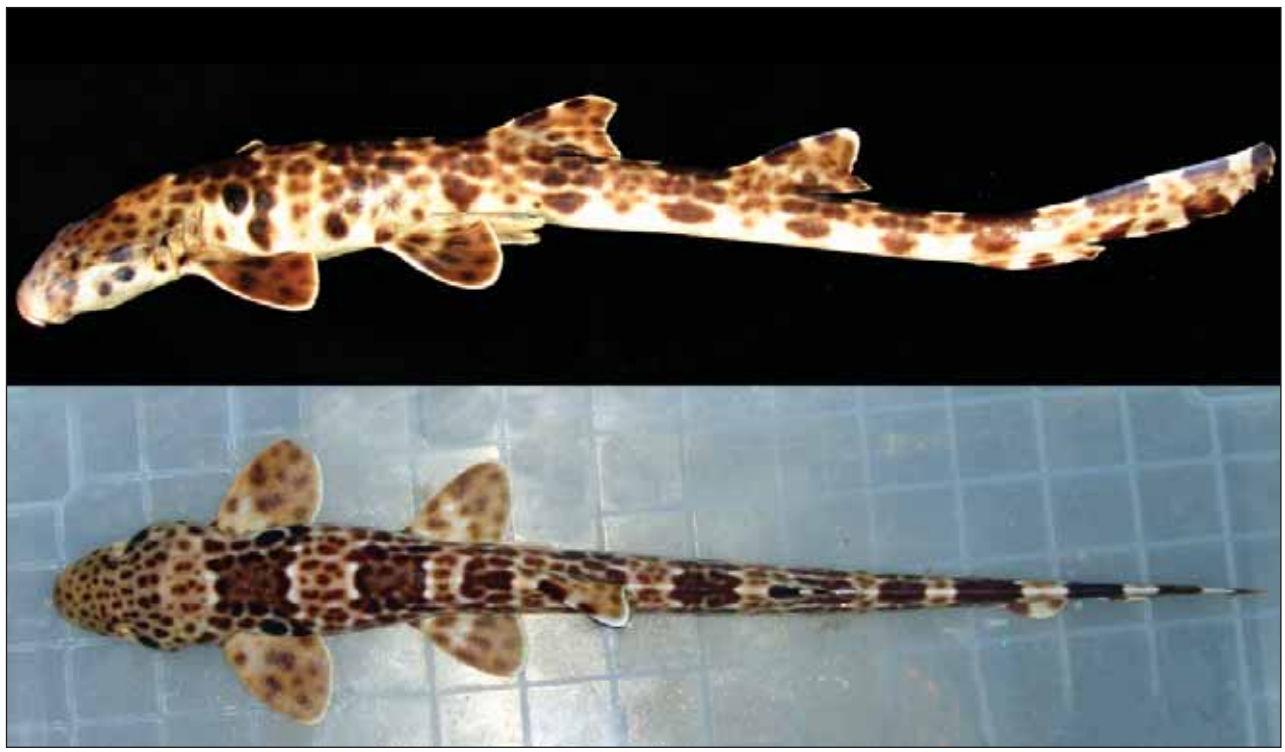

Fig. 4. Dorsal (fresh specimen) (lower) and lateral (preserved specimen) (upper), views of holotype of *Hemiscyllium galei*, 567.5 mm TL, Cenderawasih Bay, Papua Barat Province, Indonesia. Photos by G. R. Allen and M. V. Erdmann.

Table III. Inter-specific pairwise distance matrix calculated from the TrN + G model with corresponding matrix (above diagonal) of SE estimates (bootstrap method, 500 replicates).

	H. henryi	*H. ocellatum*	*H. freycineti*	*H. galei*	*C. punctatum*
H. henryi		0.00852	0.00386	0.00503	0.04048
H. ocellatum	0.03988		0.00853	0.00896	0.04422
H. freycineti	0.01058	0.03990		0.00454	0.04109
H. galei	0.01901	0.04324	0.01336		0.04373
C. punctatum	0.21586	0.22250	0.21535	0.22252	

8 on specimen photographed in 2006, Fig. 3 upper) on snout anterior to eye level; side of head with whitish area below spiracle edged posteriorly with 2-3 large, dark-brown spots, each about eye size or larger, the uppermost overlapping posterior edge of spiracle; dorsal fins each with about 4-5 poorly defined brown spots and pair of prominent blackish saddles on anterior edge; pectoral and pelvic fins with 9-13 and 8-11 variable-sized brown spots respectively on dorsal surface and narrow white posterior margin; side of body with variable-sized dark brown to blackish spots, the largest and most prominent of these arranged in horizontal row of 7-8 well-defined, horizontally-ovate, spots on the lower side between the abdomen and caudal-fin base.

Colour in alcohol (Fig. 4 upper): similar to live colour provided above, except ground colour is tan to yellowish brown and the brown spotting on the head, body, and fins is less intense.

Remarks: The new species is most similar to and obviously a close relative of *H. freycineti* (Fig. 3 lower), which inhabits shallow reefs of the western Bird's Head Peninsula, particularly the Raja Ampat Islands (Fig. 1). Colour pattern features and DNA analysis (see DNA comparison section below) provide the best means of separation between these species. Both taxa possess similar brown spotting on the head and body as well as distinctive dark saddles on the back. The configuration of the post-cephalic ocellus and associated dark bar (Fig. 5) is also remarkably similar and both species have three, vertically-oriented, large dark spots immediately posterior to the spiracle. The best means of separation is the presence of brilliant white margins on the dorsal saddles and scattered white spots in *H. galei* and lack of these markings in *H. freycineti* (compare photos in Fig. 3). In addition, *H. galei* is characterised by a row of 7-8, horizontally-ovate, dark spots on the lower side between the abdomen and caudal-fin base. In contrast, *Hemiscyllium freycineti* has pairs of leopard-like spots in approximately the same positions, but these are not well differentiated from surrounding spots and usually have paler brown centres (see Fig. 3 lower).

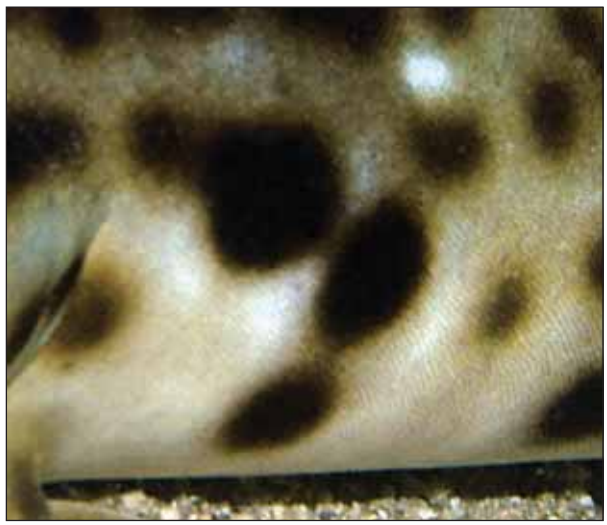

Fig. 5. Post-cephalic spots of *Hemiscyllium galei*. Photo by G. R. Allen.

The relatively large clasper size in relation to total length is probably indicative of a small maximum size for this species. The claspers on the two male types, 542.5-567.5 mm TL, are considerably larger than the similar-sized paratype of *H. henryi* (Fig. 6, Table I) and approximately the same size of those present on the 783 mm TL holotype of that species. Hemiscylliids in general are relatively small sharks. The largest specimen reported by Dingerkus & DeFino (1983) was 790 mm TL for *H. trispeculare* from Australia. Our largest example reported herein is 815 mm TL for *H. henryi* (see below).

Body proportions are generally similar among the members of the genus, although *H. galei* appears to have a relatively narrow interdorsal space and longer pelvic fins compared to other *Hemiscyllium* (Table II). However, more specimens are required to confirm these differences.

Distribution and habitat: The new species is

Fig. 6. Comparison of claspers for *Hemiscyllium henryi* (upper), 564.0 mm TL, and *H. galei* (lower), 567.5 mm TL. Photos by G. R. Allen.

apparently confined to Cenderawasih Bay, Papua Barat Province, Indonesia. The habitat typically consists of shoreline fringing reefs or shallow patch reefs. The three individuals reported to date have all been encountered at night at depths between 2-4 m. They were usually seen resting on the bottom, but occasionally were observed while slowly swimming or "walking" over the bottom with the pectoral and pelvic fins. Presumably it is sedentary during daylight hours, sheltering under rocky outcrops or tabular corals, which is typical for other family members.

Etymology: The new species is named *galei* in honour of Jeffrey Gale, an avid underwater photographer, shark enthusiast, and benefactor of the marine realm. Mr. Gale successfully bid to support the conservation of this species at the Blue Auction in Monaco on 20 September 2007 and has given generously to support Conservation International's Bird's Head Seascape marine conservation initiative.

Hemiscyllium henryi n. sp.
(Figs 2, 6-9, 11; Tables I-III)

Holotype: NCIP 6323, male, 783 mm TL, small bay in northwestern portion of Selat Iris, 03°54.544'S 134°09.679'E, immediately south of Triton Bay, Papua Barat Province, Indonesia, 3-4 m, collected by hand, M. V. Erdmann and M. Allen, 24 April 2006.

Paratypes: USNM 390771, female, 815 mm TL, patch reef near centre of Triton Bay, 03°50'01.89"S 134°05'47.94"E, Papua Barat Province, Indonesia, 3-5 m, collected by hand, M. V. Erdmann, January 2007; WAM P.32889-001, 564 mm SL, collected with USNM paratype.

Diagnosis: A species of bamboo shark belonging to the genus *Hemiscyllium*, distinguished by its unique colour pattern, particularly the combination of small scattered spots on the head, body and fins including 13-18 spots on interorbital/dorsal snout region and 6-18 spots on dorsal surface of pectoral fins, and a unique "double-ocellus" marking on middle of side, just behind the head.

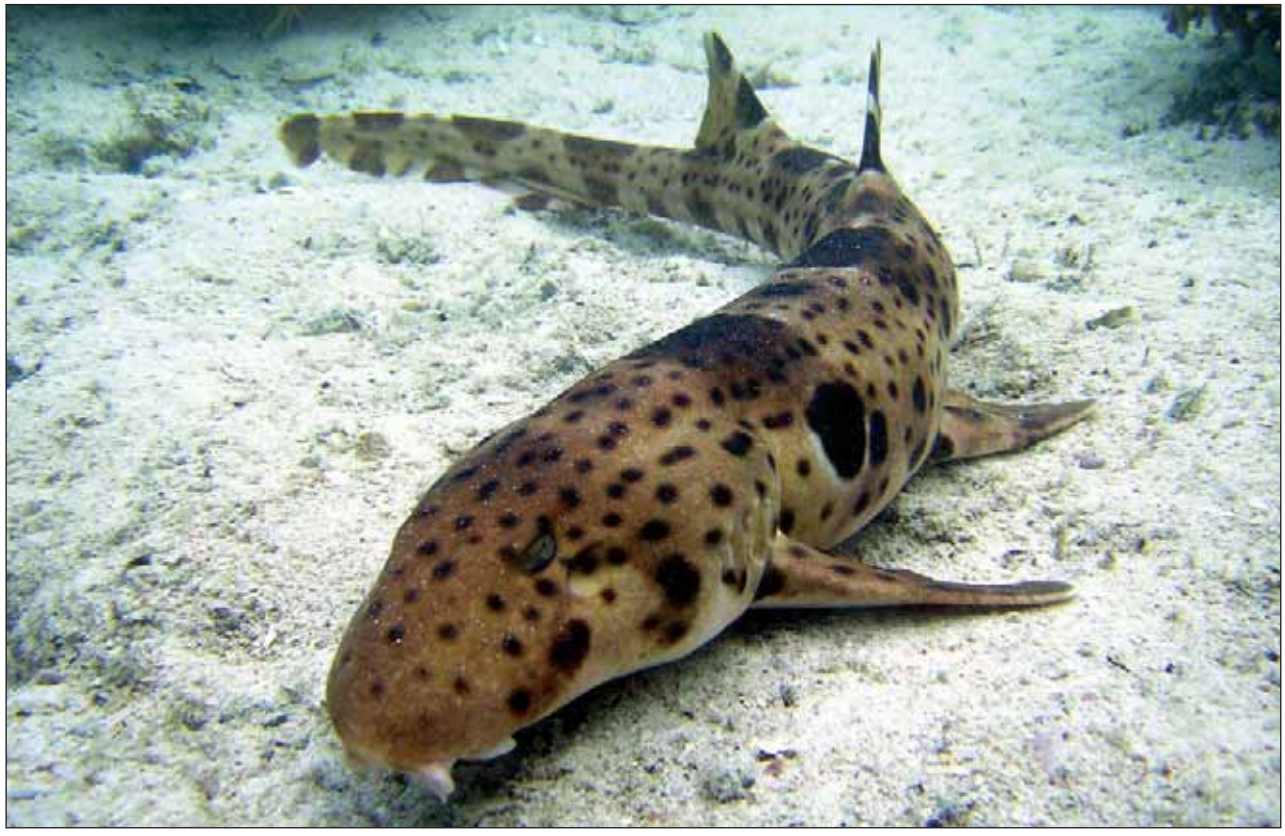

Fig. 7. Underwater photograph of *Hemiscyllium henryi*, holotype, 783 mm TL, Triton Bay vicinity, Papua Barat Province, Indonesia. Note characteristic dark spot at origin of pectoral and pelvic fins. Photo by M. V. Erdmann.

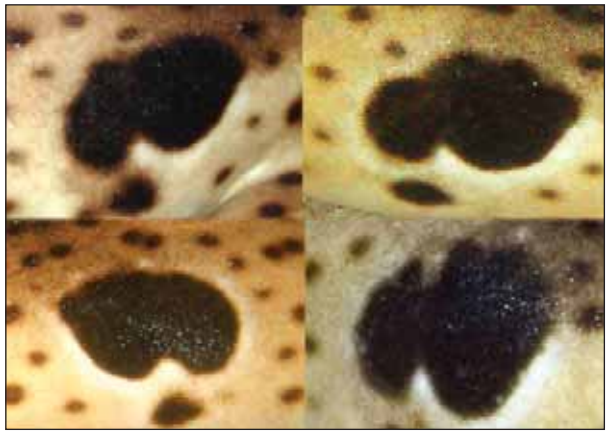

Fig. 8. Comparison of post-cephalic ocelli in four different individuals of *Hemiscyllium henryi*. Photos by G. R. Allen, M. V. Erdmann, P. Krupela, and B. Jones.

Description: Vertebral centra 193 (191-194); body and tail relatively slender, tapering posteriorly; precaudal length 1.2 (1.3), head length 7.5 (7.3), both in TL; maximum depth of head (at pectoral fin origin) about equal to width of head at level of eye; horizontal eye diameter 3.0 (3.3.6-3.8) in snout length, the vertical diameter 2.8 (2.3-2.6) in horizontal diameter; fleshy interorbital width 1.1 (1.2-1.5), bony interorbital width 1.5 (1.6-1.9), both in snout length; snout blunt and short, snout tip to eye 2.7 (2.3-2.5), snout tip to mouth 2.2 (2.7-3.1), snout tip to spiracle 2.0 (2.0-2.2), snout tip to first gill slit 1.3 (1.2), all in head length; gill slits on rear part of head, above to slightly anterior of pectoral-fin base; distance between first and fifth gill slit 2.8 (2.7-2.9) in head length; height of gill slits gradually increasing posteriorly, the first 3.3 (3.2-3.6) and fifth 2.3 (2.3-2.5), both in snout length.

Mouth small and transverse, positioned well forward on ventral surface of head (Fig. 2A), its width 1.4 in snout length; short barbel on each side of ventral snout, its length 3.0 (3.4-4.1) in snout length; maximum width of lower labial flap 3.3 (4.1-6.1), length of postoral fold (upper labial furrow) 2.8 (3.1-4.1), length of lower labial furrow 4.3 (5.0-5.1), all in snout length; teeth pavement-like, composed of numerous rows; individual teeth

Fig. 9. Dorsal and lateral views of holotype of *Hemiscyllium henryi*, 783 mm TL, Triton Bay vicinity, Papua Barat Province, Indonesia. Photo by G. R. Allen.

broad-based with single posteriorly-directed spike-like projection, the spikes of innermost rows more developed.

Snout tip to first dorsal-fin origin 2.5 (2.6-2.7), snout tip to pelvic-fin origin 3.6 (3.3-3.5), snout tip to vent 3.3 (3.2), vent to anal fin origin 2.3 (2.4), vent to tail tip 1.4 (1.4-1.5), all in TL; pectoral fins below gill openings, their length 1.3 (1.4) in TL; pelvic fins immediately anterior to vertical line passing through first dorsal fin origin, their length 1.3 (1.4) in TL; dorsal fins positioned well back on body, about equal in height; first dorsal-fin base 1.8 (1.9-2.0) in head length, first dorsal-fin height 0.9 (0.7-0.8) in first dorsal-fin base; free margin of first dorsal fin 1.7 (2.2-2.4) in first dorsal-fin height; interdorsal distance 1.0 (1.0-1.1) in head length; second dorsal-fin base 1.6 (1.7-2.0) in head length; second dorsal-fin height 1.1 (1.0) in second dorsal-fin base; free margin of second dorsal fin 1.9 (1.8-2.3) in second dorsal-fin height; a long and low anal fin just anterior to caudal fin; anal-fin base 1.5 (1.4-1.5) in head length, anal-fin height 2.8 (3.0) in anal-fin base; free margin of anal fin 1.6 (1.7-2.3) in anal-fin height; an elon-

Fig. 10. Underwater photograph of *Hemiscyllium ocellatum*, adult approximately, 700 mm TL, Great Barrier Reef, Australia. Photo by R. Steene.

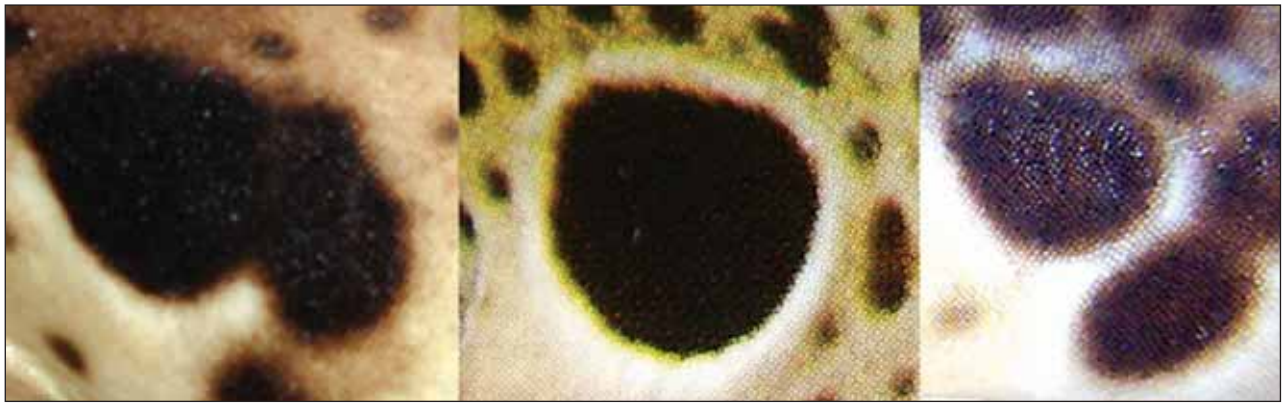

Fig. 11. Comparison of post-cephalic ocelli of: *H. henryi* (left), *H. ocellatum* (middle), and *H. freycineti*. Photos by G. R. Allen.

gated and thick precaudal tail, it depth at level of anal-fin origin 3.5 (3.5-3.6) in head length; subcaudal length 5.5 (5.6-6.0) in TL.

Male clasper stout and elongate, about same length as pelvic fin in holotype, but much reduced in smallest paratype (Fig. 6), inner length 1.3 (2.8), outer length 1.8 (9.9), both in head length; clasper width at base 4.5 (1.4), in outer length of clasper.

Colour of adults in life (Fig. 7): overall pale grey-brown, white on ventral surface, with large, well-defined and merged, "double-ocellus" marking (except separate twin ocelli on left side of holotype) on middle of side immediately posterior to head (Fig. 8), and numerous brown spots covering head and body, these becoming more numerous with increased growth; pectoral and pelvic fin

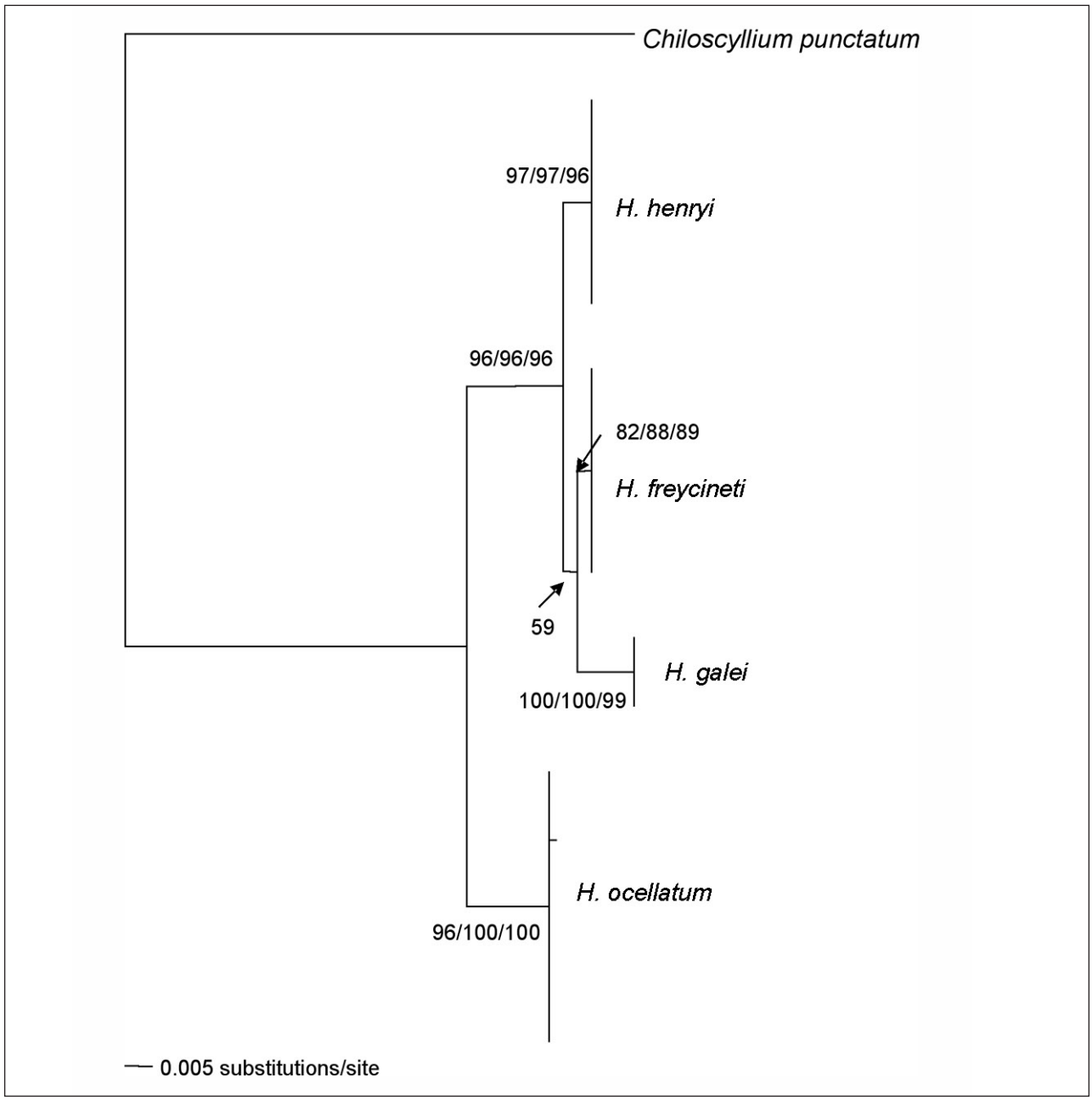

Fig. 12. Maximum Likelihood Tree (TrN + G) of the ND4 data. ML, MP and NJ bootstrap support of 1000 replications are shown, respectively. The number of specimens is shown in parentheses. The outgroup is *Chiloscyllium punctatum* Müller & Henle, 1838, a member of the only other genus in the family Hemiscyllidae.

origins with large spot; pectoral and pelvic fins with 6-18 and 6-10 variable-sized brown spots respectively on dorsal surface and narrow white posterior margin; dorsal fins largely devoid of spots (except along base) with pair of prominent blackish saddles on anterior edge.

Colour in alcohol (Fig. 9) similar to live colour provided above, except base colour is tan to yellowish brown and the brown spotting on the head, body, and fins is less intense.

Remarks: The new species is most similar to *H. ocellatum* (Bonnaterre, 1788) (Fig. 10), which inhabits shallow reefs of northern Australia between Shark Bay, Western Australia and the Great Barrier Reef with occasional vagrants reported as far south as Sydney, New South Wales. It has also been reported from New Guinea by various authors (Munro 1967; Kailola 1987; Compagno & Niem 1998; Compagno 2001), but doubtfully occurs there. Records from this locality appear to be based on misidentifications of related species.

Colour pattern features and DNA analysis (see DNA Comparisons sections below) provide the best means of separation between *H. henryi* and *H. ocellatum*. Both species possess a general pattern of brown spotting and a pair of black saddle-like markings along the anterior edge of each dorsal fin. However, they differ markedly with respect to several features, particularly the shape of the large ocellus immediately behind the head (Fig. 11). This marking is generally round in shape, intensely black, and very large (more than one-third body depth) in *H. ocellatum*. In contrast, the post-cephalic ocellus of *H. henryi* usually consists of a pair of merged ocelli, except those on the left side of the holotype, which are separated. Moreover, the surrounding white halo of *H. henryi* is poorly defined in comparison with that of *H. ocellatum.* Another difference is the presence of a dark spot at the origin of the pectoral and pelvic fins of *H. henryi* and the lack of this feature in *H. ocellatum*. In addition, the dark brown saddle-like markings and bars characteristic of the new species are weakly developed in *H. ocellatum*. A final difference concerns the presence of numerous small brown spots on the dorsal fins of *H. ocellatum*, in contrast to the mainly spotless pattern of *H. henryi.* Although additional specimens are required to strengthen the data, *H. henryi* appears to have taller first dorsal and anal fins compared to other *Hemiscyllium* (Table II).

The largest paratype contained eight full-sized ova ranging in diameter between about 25-30 mm.

Distribution and habitat: The new species is known only from western New Guinea (Papua Barat Province, Indonesia) in the vicinity of Triton Bay in the southern Bird's Head region. It has been observed/collected both in the bay and at nearby Selat Iris, a narrow channel between the mainland and Aiduma Island. Unlike other parts of the Bird's Head Peninsula such as Cenderawasih Bay and the Raja Ampat Islands, there is almost no shallow, fringing reef habitat due to the unique geomorphology of the area. Hence, the typical habitat for this shark extends into deeper water (at least 30 m), although it has also been sighted in depths less than 4 m. It is usually seen resting on the bottom, but occasionally is observed while slowly swimming or "walking" over the bottom with the pectoral and pelvic fins. During the day it is generally sedentary, sheltering under rocky outcrops or tabular corals.

Etymology: The species is named *H. henryi* in honour of Wolcott Henry of Washington D.C., who has generously supported Conservation International's marine initiatives, including taxonomy of western New Guinea fishes.

DNA COMPARISONS

We analysed a 791 base pair (bp) fragment from the ND4 gene and adjacent tRNA genes in 15 individuals from the following four species of *Hemiscyllium*: *H. henryi* (n = 4); *H. ocellatum* (n = 5); *H. freycineti* (n = 4); *H. galei* (n = 2). Of these, 38 bp were variable with 37 parsimony informative characters. Nucleotide frequencies were as follows: A = 0.31, C = 0.25, G = 0.11, T = 0.32. The transition : transversion ratio was 7.8:1. A total of five haplotypes was detected. All species had only one haplotype except for *H. ocellatum* that showed two haplotypes, one found in four individuals and the other from one individual. Pairwise distances *(d)* between the *Hemiscyllium* spp. ranged from 0.01058 to 0.04324 with *H. ocellatum* differing from the other species by at least twice the distance (Table III). Pairwise distances between the *Hemiscyllium* spp. and the outgroup *Chiloscyllium punctatum* were an order of magnitude higher (d_{ave} = 0.21906). Only *H. ocellatum* had more than one haplotype and therefore showed within species distances. This was over two orders of magnitude lower than the within-genus distances, d = 0.00051 ± 0.00052.

Maximum likelihood, maximum parsimony and neighbour-joining analyses for both model types

resulted in identical tree topologies (Fig. 12) revealing reciprocal monophyly of the four *Hemiscyllium* species with high bootstrap support. Only maximum likelihood resulted in >50% bootstrap support to *H. freycineti* and *H. cendrawasih* forming a sister clade to *H. henryi*.

Based on these results there is strong phylogenetic support for monophyletic clades of each *Hemiscyllium* species. All three tree methods produced similar tree topology. In addition, bootstrap values for each monophyletic clade are high. Although actual genetic divergence values are relatively low, it is difficult to interpret these data due to a general lack of comparative data for hemiscylliids and other sharks, at least in published literature. The interspecific divergence values for *Hemiscyllium* generally range from 1% to 4%.

Key to the Species of *Hemiscyllium*

1a. Head and snout with an abrupt black hood; body covered with conspicuous large white spots (eastern Papua New Guinea) ..... *H. strahani*

1b. Head and snout light, without a black hood but with conspicuous black spots above pectoral fins; body with inconspicuous light spots or spots absent 2

2a. Dark spot behind gills relatively small, forming a weak ocellus (or semi-ocellated dark spot) and followed posteriorly by dark brown bar (consisting of 2-3 merged spots in vertical row) 3

2b. Dark spot behind gills large, forming 1-2 conspicuous white-rimmed ocelli or merged double ocelli without dark brown bar immediately behind 4

3a. Network of white lines/spots mainly associated with edge of large dark saddles on back; conspicuous row of 7-8 large, horizontally-oval, dark spots along lower side (Cenderawasih Bay, Papua) ..... *H. galei*

3b. Network of white lines/spots mainly associated with edge of large dark saddles on back absent; row of dark spots along lower side relatively inconspicuous and not well differentiated from surrounding spots (Raja Ampat Islands, western Bird's Head region, Papua) ... *H. freycineti*

4a. Head, body, and fins covered with polygonal, leopard-like spots (Milne Bay Province, Papua New Guinea) ..... *H.* species

4b. Head body, and fins covered with numerous spots, but more or less round in shape and not polygonal and leopard like 5

5a. Body covered with numerous, densely clustered dark small and large spots that form a reticular network of light base colour between them; dark cross bands strong on ventral surface of tail (northern Australia) ..... *H. trispeculare*

5b. Body with more sparse, large spots that do not form a reticular network of light ground colour between them; dark cross bands on tail relatively weak or not reaching ventral surface 6

6a. Lateral ocellus surrounded by large black spots; spots absent on head in front and below eyes (southeastern Papua New Guinea) ..... *H. hallstromi*

6b. Lateral ocellus surrounded by relatively small spots; spots present on head in front and below eyes 7

7a. Lateral ocellus composed of single large, round spot surrounded by distinct white halo; dark spot absent at origin of pectoral and pelvic fins; numerous small dark spots usually present on dorsal fins (northern Australia) ..... *H. ocellatum*

7b. Lateral ocellus usually composed of double, merged ocelli surrounded by poorly defined white halo; dark spot present at origin of pectoral and pelvic fins; dorsal fins usually without small dark spots or if present they are restricted to basal portion of fins (Triton Bay vicinity of Bird's Head region, Papua) ..... *H. henryi*

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