The unexpected discovery of blind snakes (Serpentes: Typhlopidae) in Micronesia: two new species of *Ramphotyphlops* from the Caroline Islands

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Abstract

Two new blind snakes in the genus *Ramphotyphlops* are described from Ulithi (*R. hatmaliyeb* **sp. nov.**) and Ant Atoll (*R. adocetus* **sp. nov.**) in the Caroline Islands, the first blind snake species known from Micronesia east of Palau (excluding *Ramphotyphlops braminus*). Both species are unusual in being known only from small, low-lying atolls. They can be dis tinguished from other *Ramphotyphlops* by the combination of 22 scale rows over the length of the body; a wedge-shaped snout, without a keratinized keel; and a broad, pyriform (*R. adocetus*) or ovate (*R. hatmaliyeb*) rostral scale.

Key words: Ant Atoll, arboreality, hemipenes, Oceania, Scolecophidia, Ulithi

Introduction

Blind snakes (Scolecophidia, family Typhlopidae) comprise approximately 250 nominate species (Uetz and Hosek 2011) with a distribution primarily in tropical and sub-tropical regions worldwide. Although there are numerous species in such archipelagos as the Greater and Lesser Antilles, the Philippines, and the Solomon Islands, none are known to have reached the many islands of Oceania north of Melanesia and east of Palau (with the exception of *Ramphotyphlops braminus*, a parthenogenetic species [McDowell 1974; Wynn *et al.* 1987; and Ota *et al.* 1991] known for its human-mediated dispersal abilities).

More than 30 blind snake species occur in the island arc bordering the western Pacific, from the Philippines in the northwest to Fiji in the southeast (McDiarmid *et al.* 1999; McDowell 1974; Watling *et al.* 2010) (Fig. 1). Only two species are reported to extend into Oceania to the north and east of this arc. Dryden and Taylor (1969) described *Typhlops pseudosaurus* from Guam (now regarded as *Ramphotyphlops braminus* [McDiarmid *et al.* 1999]), based on a shedding specimen (not an aberrant *R. braminus* as suggested by Pregill and Steadman 2009). *Ramphotyphlops acuticaudus* from Palau (Crombie and Pregill 1999), a species similar to *Ramphotyphlops flavi venter* and related species from Halmahera eastward through New Guinea and the Solomon Islands to Fiji (McDowell 1974; Wallach 1996; Watling *et al.* 2010), is the only recognized species that occurs inside this island arc, and other than *R. braminus*, no blind snakes occur eastward in Micronesia.

Two recent discoveries reveal that blind snakes occur, potentially widely, within the Caroline Islands. On 15 July 1999, a specimen of typhlopid (USNM 529971) was collected on Pasa Island, Ant Atoll by Otto Sirom, who found the snake inside a rotted *Cocos* trunk that was lying on the ground. Subsequently, one of us (M. Falanruw) alerted the other authors to the presence of blind snakes that she had collected on Ulithi, approximately 2000 km to the west of Ant Atoll. Comparison of these specimens from Ant Atoll and Ulithi, along with more recently col lected specimens, indicate that they represent two similar undescribed species of *Ramphotyphlops*, which we describe below.

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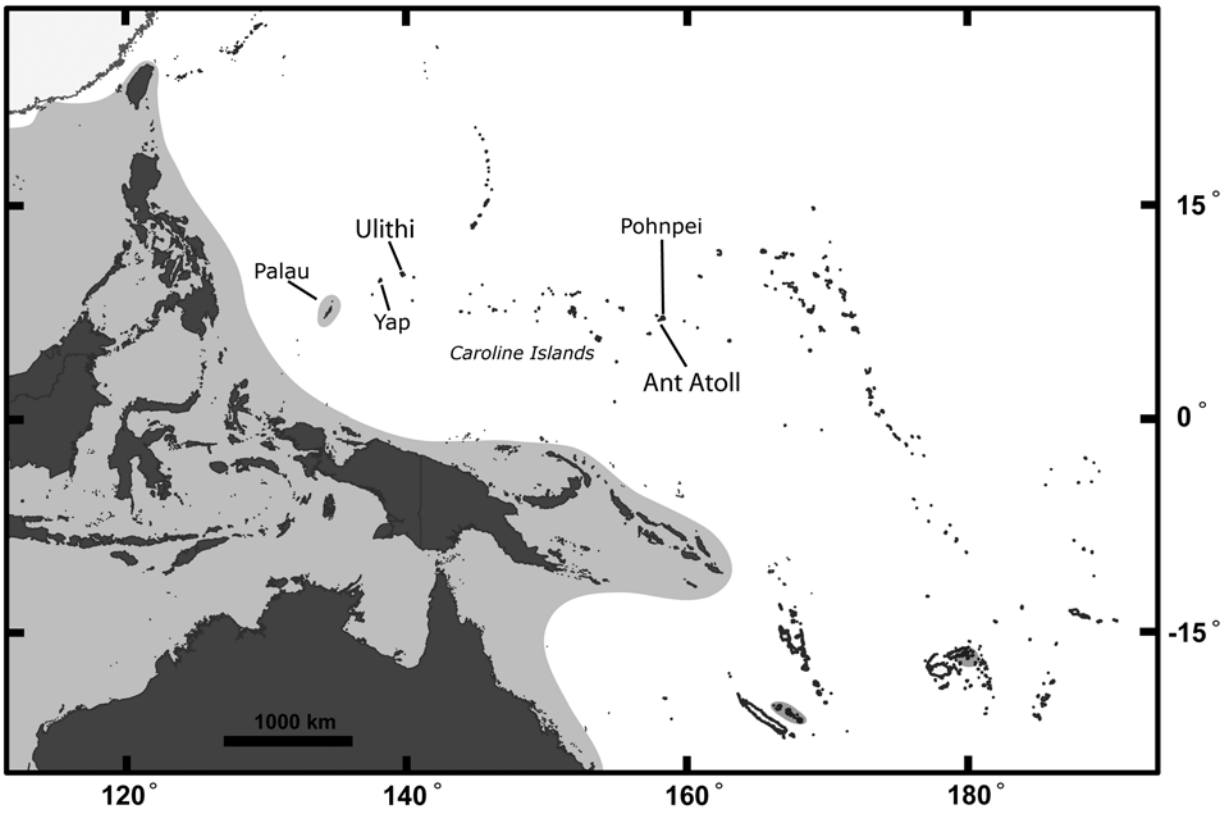

FIGURE 1. The location of Ulithi and Ant Atoll in the Caroline Islands. The shaded region encompasses the general area in which blind snakes (not including *Ramphotyphlops braminus*) are known from the region bordering the western Pacific Ocean.

Methods

Middorsal scale rows were counted between the rostral and terminal scale. The number of middorsocaudal scales was counted as the number of middorsals posterior to the transverse scale row at the level of the lateralmost preanal scale and anterior to the terminal scale. Counts of middorsal and middorsocaudal scales do not include the interca lary scales unless stated. The number of middorsocaudals can sometimes differ when counted from one side of the vent versus the other. Counts based on counting from both the left and right of the vent are given in Table 1, and an average of the two was used in Fig. 3 when the two counts differ. Total length was measured with a ruler to the nearest millimeter. All other measurements were made to the nearest 0.1 mm with an optical micrometer. The body, tail, and eye diameters were measured in the horizontal plane, rostral width was measured from the lateralmost extent of the scale's free edges near the anterior tip of the snout, and head width was measured at the level of the midpoint of the eyes. Descriptions of head scale shape and scale size measurements are based on the overlying scale plate, not the underlying scale delineated by bordering gland rows. References to pigmentation in the descrip tions of coloration refer to the presence or absence of melanophore pigmentation in preserved specimens. In descriptions of dorsal stripe width, scale rows are counted lateral to the middorsal. Radiographs were produced with a Kevex Microfocus x-ray source and a Varian flat-panel digital x-ray image detector. Museum abbreviations follow Leviton *et al.* (1985).

***Ramphotyphlops adocetus* sp. nov.**
(Figs. 2, 7A)

Holotype. USNM 529971, an adult male from Pasa Island, Ant Atoll, Caroline Islands (Federated States of Micro nesia), collected by Otto Sirom on 15 July 1999.

Paratypes. USNM 558284–558299, Pasa Island, Ant Atoll, Caroline Islands (Federated States of Micronesia), collected by Brian Lynch and Donald W. Buden on 30 August 2008.

Diagnosis. *Ramphotyhlops adocetus* can be distinguished from other Indoaustralian and Philippine typhlopids by the combination of 22 scale rows over the length of the body; the wedge-shaped snout, without a keratinized keel; and its broad, pyriform rostral.

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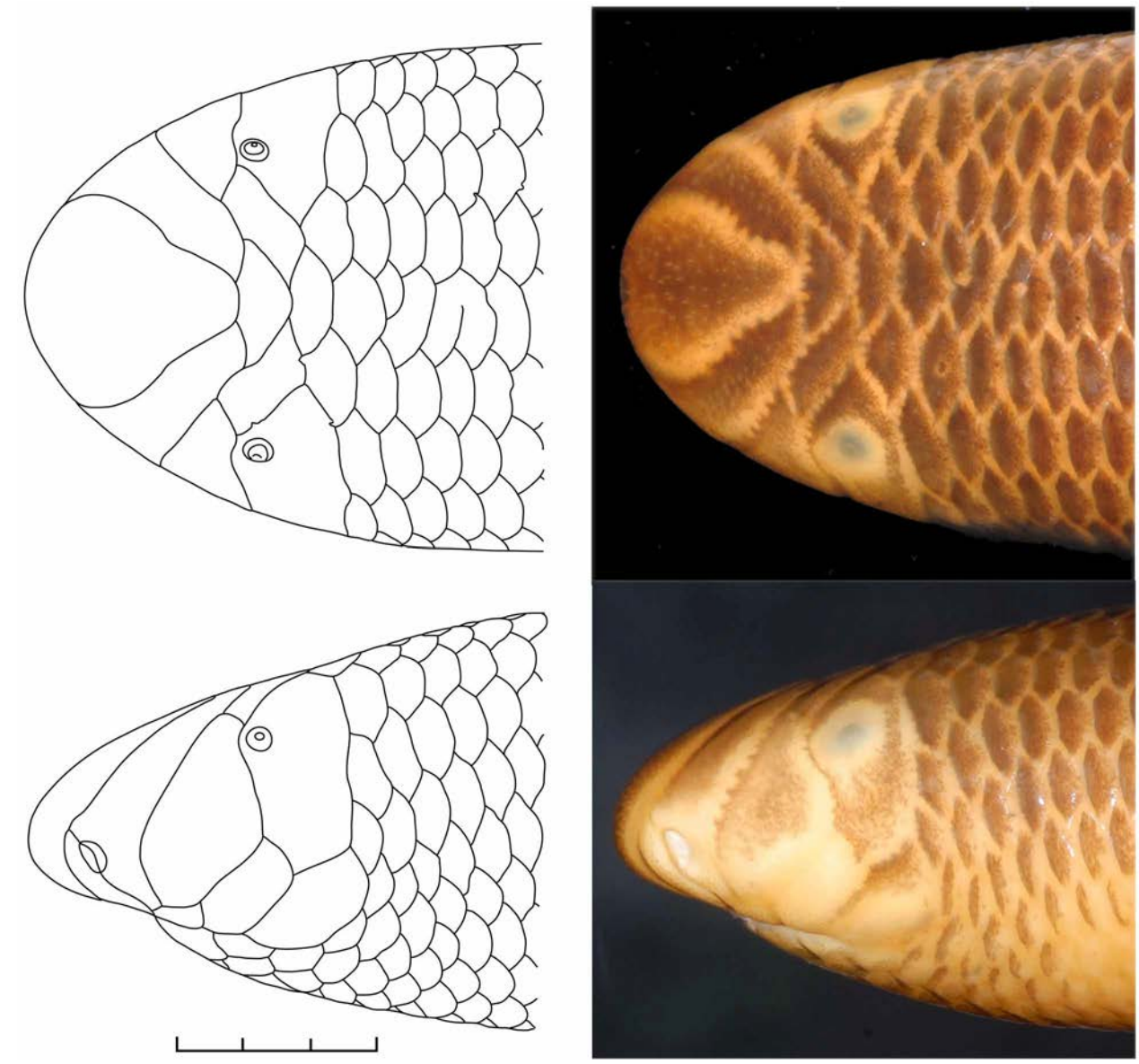

FIGURE 2. Dorsal (top) and left lateral (bottom) views of the head of the holotype of *Ramphotyphlops adocetus* (USNM 529971). The illustration of the scale pattern on the left is based on the free edge of the scale plates. The scale bar represents three millimeters.

Description of holotype. Male, total length 373 mm, tail length 20.1 mm, midbody diameter 9.8 mm, body diameter at vent 8.3 mm, diameter near midpoint of tail 7.2 mm. Middorsal scale rows 461 (not including interca lary scales), 476 (including intercalary scales—12 on left, 3 on right). Middorsocaudal scales 32 (not including two intercalary scales). Twenty-two scale rows around head (beginning about three transverse scale rows posterior to fourth supralabial) and continuing for length of body to about 4 mm anterior to vent, where paramidventral row on left divides at eight transverse rows anterior to vent, and paramidventral row on right divides at six transverse rows anterior to vent, with 24 scale rows around body from there to vent. Head tapered with rounded anterior tip when viewed from above; dorsal surface of snout sloped giving head a wedge shape in lateral profile; a keratinized beak absent (Fig. 2). Eyes distinct, ca. 0.4 mm in diameter, lying beneath unpigmented windows in ocular scales.

Details of the head scalation can be seen in Fig. 2. Salient features are: superior internasal suture short, incom pletely dividing the nasal scale, extending forward obliquely from the nostril and extending under the rostral free edge (but not penetrating the gland row under the rostral free edge), an underlying gland row not clearly visible; inferior internasal suture extending from the nostril to the second supralabial, with an underlying gland row. Ros tral strongly pyriform viewed from above, 3.1 mm in width at its broadest (52% head width), then tapering to a rounded posterior tip. Four supralabial scales, increasing in size from first to last, with the third and fourth nearly equal in size and much larger than the first and second. The first supralabial (not visible in Fig. 2) is overlapped by the prenasal and overlaps the second supralabial. The second supralabial is about twice the size of the first, over

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lapped by the prenasal, postnasal, and preocular, and overlaps the third supralabial. The third supralabial extends dorsally to the level of the nostril, is overlapped by the preocular and overlaps the ocular and fourth supralabial. The fourth supralabial also extends dorsally to the level of the nostril, and is overlapped by the ocular. There are three postoculars on each side.

The dorsum is covered with dark brown melanophore pigmentation. On the head, this pigmentation covers the entire dorsal surface of the rostral, extending anteriorly and ventrally around the tip of the snout to the anteriormost ventral surface of the rostral; the prefrontal, frontal, interparietal, supraoculars, and parietals; the postnasals dorsal to the nostrils; the dorsal half of the right preocular, and all but the ventralmost left preocular; the oculars surround ing the unpigmented eye-windows; and the anterior edge and dorsal apex of the left fourth supralabial, and ante rior- and dorsalmost edge of the right fourth supralabial. Immediately posterior to the fourth supralabial, dorsal pigmentation extends ventrally as a band of pigmented scales, three to five transverse scale rows in width, around the head to the ninth longitudinal row, with a gap of three unpigmented ventral rows (the midventral and two par amidventral scale rows).

Posterior to this band, the body has a dark brown longitudinal stripe 13 scale rows wide (the middorsal and six lateral scale rows on either side), with the scales in the middorsal and five lateral rows to either side continuously pigmented for the length of the body, but with scattered unpigmented scales occurring in the sixth lateral row, giv ing the stripe a ragged-appearing edge. Outside of this stripe, a few pigmented scales are scattered along the sev enth lateral row, and two pigmented scales are present in the eighth row (both scales on the right side). The dorsal stripe increases in width to include most scales in the seventh lateral row approximately 4 mm anterior to the vent, and the proportion of pigmented scales in the eighth lateral row increases at the level of the vent. Beyond the vent, the dorsal stripe continues as a nearly straight-edged stripe, 17 rows wide for the first 5 mm posterior to the vent, after which the eighth row lateral to the middorsal becomes intermittently pigmented, but the seventh row remains continuously pigmented to near the tail tip, where loss of the scale row to either side of the middorsal reduces the width of the stripe from 15 rows to 13 rows in width. The terminal scale is pigmented. Other scales on the ventral head, body, and tail lack melanophore pigmentation.

Although sharply demarcated from the unpigmented scales on the venter, the dorsal stripe is darkest middor sally and gradually becomes paler laterally due to decreasing pigment density in the scales. In the lateralmost rows, the extent of pigmentation also decreases in the posterior and ventral portion of the scales, with pigmentation found in only the anterior half or less of many scales in the sixth row, and the anterior half or less in the pigmented scales in the seventh row from the middorsal.

The tail tapers only slightly for the first three-quarters of its length posterior to the vent, after which it tapers more abruptly to the tail tip; the terminal scale is cone shaped with a sharp keratinized spine.

A rectal caecum is not present. Retrocloacal sacs are present, both left and right extending into the body cavity for about 8 mm anterior to the level of the vent (about 2% of the body length). Exposed by dissection of the tail, the left inverted hemipenis is straight for its proximal half followed by two major coils in its distal half.

Variation. Total length 154–390 mm, middorsal scales 447–474. Tail length appears to be sexually dimorphic. Although there is no obvious difference in the number of middorsocaudals between males and females, males tend to have relatively longer tails (Table 1, Fig. 3). In addition, all males have tails with little taper through most of their length and with an abruptly tapered tip. In contrast, all females have tails that taper gradually through their postoculars (three fully contacting the posterior edge of the ocular, the fourth wedged between the dorsalmost two of these three, and with only partial contact with the ocular) on the left side of the head, and the other (USNM 558286) has two postoculars on the left side of the head, the dorsalmost postocular spanning the width of the sec ond and third longitudinal scale rows lateral to the middorsal, apparently resulting from fusion of the two postocu lars corresponding to these two rows. The superior internasal suture extends under the rostral free edge (but does not penetrate the gland row at the edge of the rostral scale) in 12 paratypes. In the remaining four specimens, all in shedding condition, the superior internasal suture ends before the rostral free edge. Although no gland was clearly seen underlying the superior internasal suture in the holotype, a small round or oval gland could be seen underlying the superior internasal suture near its terminus under the rostral free edge in nine of the paratypes. All specimens have 22 scale rows around the body posterior to the head until just anterior to the tail where the paramidventral scale rows divide five to seven transverse rows anterior to the vent in 15 specimens, 10 rows in one specimen, to increase the number of rows around the body to 24. The color pattern of all paratypes (except four specimens in shedding condition, in which some details of the color pattern cannot be clearly discerned) is similar to that of the holotype. Five of the paratypes have pigmentation (in the dorsal and/or anterior portion of the scale) in one or both

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of the third supralabials, in addition to pigmentation in the fourth supralabials. All specimens also have a dorsal stripe that is 13 longitudinal rows in width on the body, with the sixth lateral row varying from being completely pigmented (no unpigmented scales in the row) to having scattered unpigmented scales in the row. A few pigmented scales are also scattered along the seventh lateral row in all paratypes, as in the holotype, except for two specimens. USNM 558288 has an approximately equal number of pigmented and unpigmented scales in the seventh row, and USNM 558291 has an approximately equal number of pigmented and unpigmented scales anteriorly in the row, but fewer unpigmented scales posteriorly in the row. Most specimens also have a few pigmented scales scattered along the eighth lateral row on one or both sides (as many as 12, but usually four or fewer). Tail coloration is similar to the holotype in all specimens, the dorsal stripe expanding to 17 rows in width near the level of the vent, then con tinuing either 15 or 17 rows in width to near the tip, where the width is reduced by longitudinal scale row loss. In addition to the holotype, a rectal caecum was searched for, but not found, in one other specimen (USNM 558295).

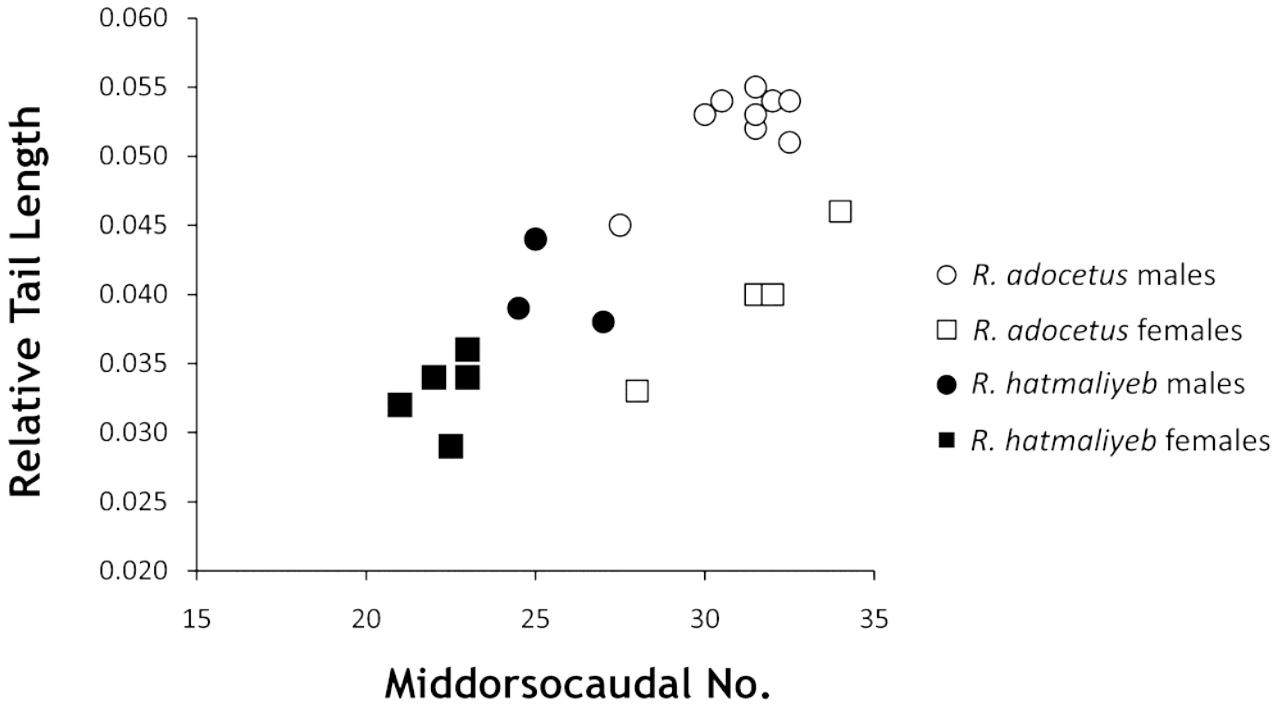

FIGURE 3. The relationship between relative tail length (tail length/total length) and the number of middorsocaudal scales in male and female specimens of *Ramphotyphlops adocetus* and *R. hatmaliyeb*.

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TABLE 1. Measurement, scale count, and tail length ratio data for the type specimens of *Ramphotyphlops adocetus* and *R. hatmaliyeb*. MD# =the number of middorsal scales; MDC = the number ofmiddorsocaudals.

Species	USNM	Total Length (mm)	Tail Length (mm)	Tail Length/ Total Length	MD#	MDC (left)	MDC (right)	Post-Ocular # (left)	Post-Ocular # (right)	Dorsal Stripe Width	Left Hemi-penis Length (mm)	Rt. Hemi-penis Length (mm)	Sex	Locality
R. adocetus	529971	373	20.1	0.054	461	32	32	3	3	13			male	Ant Atoll: Pasa Id.
R. adocetus	558284	390	20.1	0.052	456	31	32	3	3	13	30		male	Ant Atoll: Pasa Id.
R. adocetus	558285	154	7.6	0.049	467	32	33	3	3	13			juv.	Ant Atoll Pasa Td.
R. adocetus	558286	331	17.6	0.053	459	31	32	2	3	13		33	male	Ant Atoll: Pasa Td.
R. adocetus	558287	364	19.9	0.055	461	31	32	4	3	13			male	Ant Atoll : Pasa Td.
R. adocetus	558288	307	14.0	0.046	460	34	34	3	3	13			female	Ant Atoll Pasa Id.
R. adocetus	558289	342	13.6	0.040	474	31	32	3	3	13			female	Ant Atoll Pasa Id.
R. adocetus	558290	252	10.0	0.040	464	32	32	3	3	13			female	Ant Atoll: Pasa Id.
R. adocetus	558291	236	7.8	0.033	449	28	28	3	3	13			female	Ant Atoll: Pasa Td.
R. adocetus	558292	180	8.5	0.047	447	29	29	3	3	13			juv	Ant Atoll Pasa Td.
R. adocetus	558293	202	8.8	0.044	466	33	34	3	3	13			juv.	Ant Atoll : Pasa Td.
R. adocetus	558294	157	6.7	0.043	465		30	3	3	13			juv.	Ant Atoll Pasa Id.
R. adocetus	558295	345	18.7	0.054	?	30	31	3	3	13	36		male	Ant Atoll Pasa Id.
R. adocetus	558296	383	20.3	0.053	461	30	30	3	3	13			male	Ant Atoll Pasa Id.
R. adocetus	558297	361	19.4	0.054	459	32	33	3	3	13	47		male	Ant Atoll: Pasa Id.
R. adocetus	558298	380	19.5	0.051	463	32	33	3	3	13		40	male	Ant Atoll Pasa Id.
R. adocetus	558299	367	16.6	0.045	468	27	28	3	3	13	37	35	male	Ant Atoll : Pasa Td.
R. hatmaliyeb	558300	331	10.5	0.032	462	21	21	2	2	▮ ▮			female	Ulithi: Giilab Id.
R. hatmaliyeb	558301	354	112	0.032	465	21	21	2	2	▮ ▮			female	Ulithi: Giilab Id.
R. hatmaliyeb	558302	352	13.7	0.039	466	24	25	3	2	11			male	Ulithi : Giilab Id.
R. hatmaliyeb	558303	416	14.2	0.034	467	22	22	2	2	13			female	Ulithi: Giilab Id.
R. hatmaliyeb	558304	295	10.5	0.036	464	23	23	3	3	▮ ▮			female	Ulithi: laar Id.
R. hatmaliyeb	558305	255	9.7	0 038	472	27	27	3	2	▮▮			male	Ulithi: Bulbulld.
R. hatmaliyeb	558306	228	10.1	0.044	452	25	25	2	2	▮ ▮			male	Ulithi Piig Id.
R. hatmaliyeb	558307	340	11.5	0.034	469	23	23	2	2	13			female	Ulithi: Soong Id
R. hatmaliyeb	558308	178	6.3	0.035	465	24	23	3	3	13			juv.	Ulithi: Soong Id
R. hatma/iyeb	558309	297	10.1	0.034	465	22	22	3	3	11			tem ale	Ulithi: Soong Td.
R. hatma/iyeb	558310	380	11.0	0.029	460	23	22	3	3	13			temale	Ulithi: Soong Td.

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Protruded hemipenes (right, left, or both) are present in six males, for a total of ten hemipenes; nine appear to be fully protruded and one is clearly incompletely protruded. Of the nine fully protruded hemipenes, one was not measured due to its desiccated condition and one is too contorted to accurately measure. Six of the seven remaining hemipenes have helical coils and hairpin loops to varying degrees that make accurate measurement difficult, and the resulting measurements are probably underestimates of their lengths. These six vary in length from 30 to 40 mm and from 1.5 to 2.2 times the tail length. One protruded hemipenis (USNM 558297) (Fig. 4) is fully straight and 47 mm in length, 2.4 times the length of the tail. All hemipenes are slender, solid awns (*sensu* McDowell 1974), less than 1 mm in diameter, that taper slightly along their length to a slightly constricted neck about 1 mm from the tip, which is followed by an expanded head with a bluntly pointed tip. For example, USNM 558297 has a diameter of about 0.8 mm at its base, tapers to 0.5 mm diameter just before the constricted neck, which is 0.8 mm from its tip, then expands in diameter to 0.5 mm before tapering to a rounded tip. A sulcus spermaticus runs the length of the hemipenes, ending at the tip. These hemipenes differ in two respects from the hemipenes of other *Ramphotyphlops* that we are familiar with. First, in both *R. acuticaudus* (USNM 558274 and 558282) and *R. cumingii* (National Museum of the Philippines/Cincinnati Museum of Natural History Philippine Biodiversity Inventory H-1547), the proximal portion of the protruded hemipenis is an expanded, fleshy base that appears to be everted, with a long, slender awn extending from a depression in its tip. In contrast, all hemipenes of *R. adocetus* are an awn extending directly from the vent, without an everted base. Although this differs from the hemipenes that we have observed in *R. acuticaudus* and *R. cumingii*, it is similar to the hemipenis of *R. ligatus* described and illustrated by Robb (1960: fig. 22; 1966: fig. 1). Second, in *R. acuticaudus* and *R. cummingii* the awn tapers gradually to a pointed tip, without the constricted neck or blunt, cone-like head at the tip of the awn observed in *R. adocetus*.

Etymology. The specific name *adocetus* is derived from the Greek *adoketos* meaning "unexpected or surprising," in reference to the unexpected discovery of this species on a remote Pacific atoll.

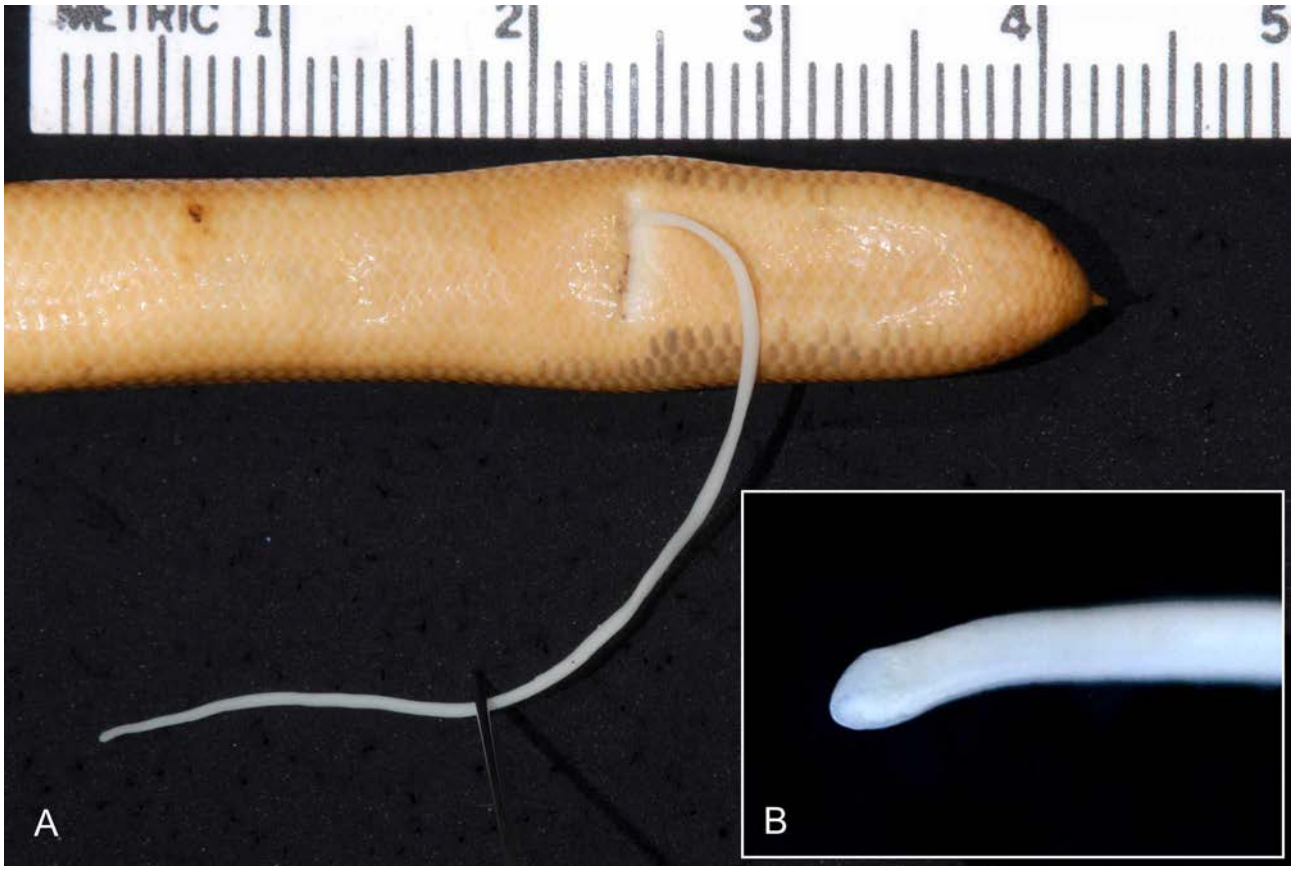

FIGURE 4. The left protruded hemipenis of *Ramphotyphlops adocetus*, USNM 558297. The inset shows the tip of the hemipenis.

***Ramphotyhlops hatmaliyeb* sp. nov.**
(Figs. 5, 7C)

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Holotype. USNM 558300, from Giilab (= Gielap, Gielop) Island, Ulithi, Caroline Islands (Federated States of Micronesia), collected by Marjorie Falanruw on 04 August 2007.

Paratypes. USNM 558301–558303, Giilab Island; USNM 558304, Iaar Island; USNM 558305, Bulbul Island; USNM 558306, Piig Island; and USNM 558307–558310, Soong Island; all part of Ulithi, Caroline Islands (Feder ated States of Micronesia).

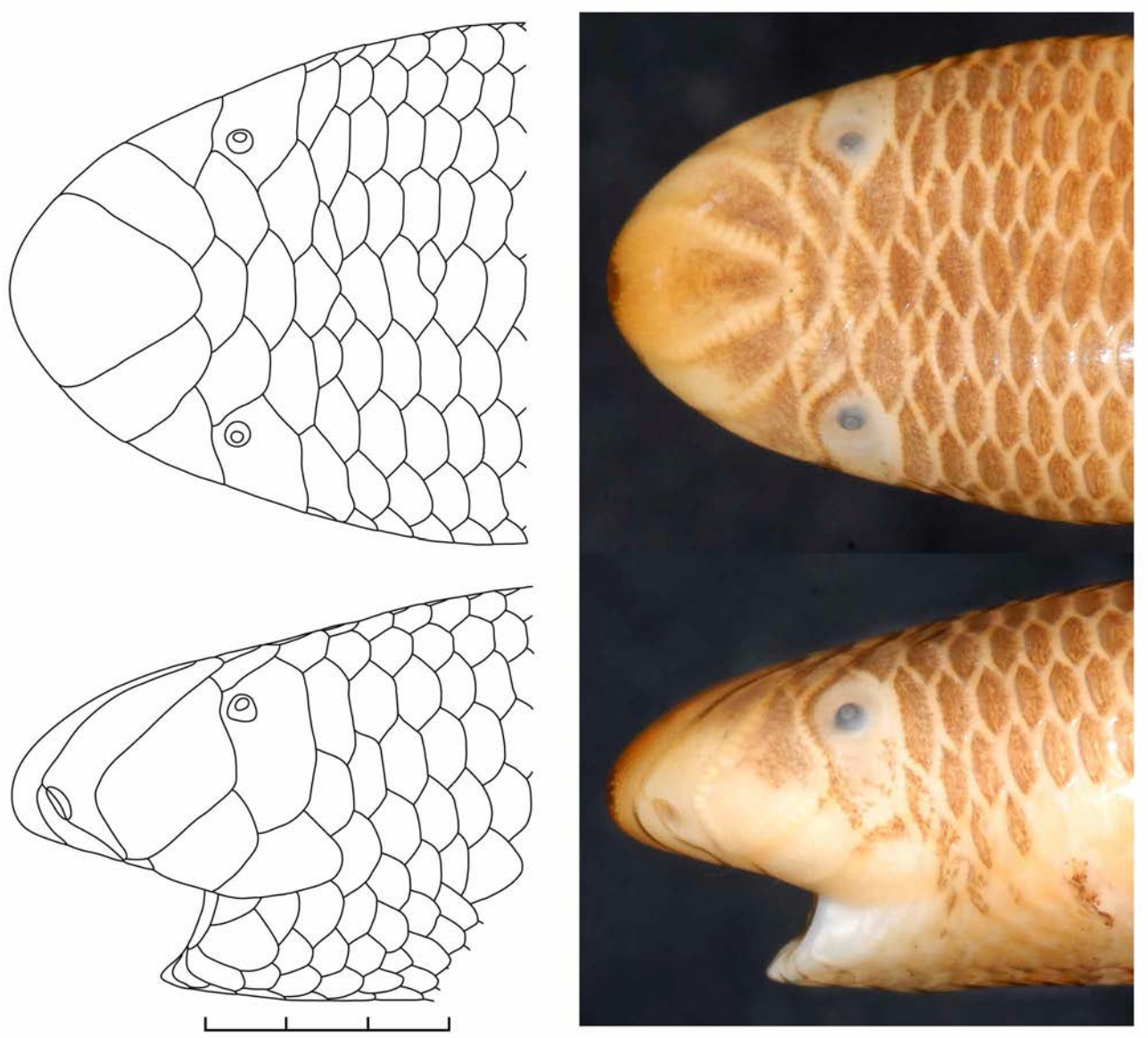

FIGURE 5. Dorsal (top) and left lateral (bottom) views of the head of the holotype of *Ramphotyphlops hatmaliyeb* (USNM 558300). The illustration of the scale pattern on the left is based on the free edge of the scale plates. The scale bar represents three millimeters.

Referred specimen. USNM 558311, Dorooleng Island, Ulithi, Caroline Islands (Federated States of Microne sia).

Diagnosis. *Ramphotyhlops hatmaliyeb* can be distinguished from other Indoaustralian and Philippine typhlopids by the combination of 22 scale rows over the length of the body; the wedge-shaped snout, without a ker atinized keel; and its broad, ovate rostral.

Description of holotype. Female, total length 331 mm, tail length 10.5 mm, midbody diameter ca. 8 mm, body diameter at vent 6.6 mm, diameter near midpoint of tail 5.5 mm. Middorsal scale rows 462 (not including intercalary scales), 466 (including intercalary scales—1 on left, 3 on right). Middorsocaudal scales 21 (count approximate due to irregularities in scale pattern of middorsal row, excludes one intercalary scale in middorsal row). Twenty- two scale rows around head (beginning about four transverse scale rows posterior to fourth supralabial) and con- tinuing for length of body to about 3.3 mm anterior to vent, then 24 rows around body for last six transverse rows anterior to vent due to division of both paramidventral scale rows. Head tapered with a rounded anterior tip when viewed from above; dorsal surface of snout sloped to give head a wedge shape in lateral profile; a

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keratinized beak absent (Fig. 5). Eyes distinct, ca. 0.4 mm in diameter, lying beneath unpigmented windows in ocular scales.

Details of the head scalation can be seen in Fig. 5. Salient features are: superior internasal suture short, incompletely dividing the nasal, extending forward obliquely from the nostril and extending under the rostral free-edge (but not penetrating the gland row under the rostral free edge) with a small, oval gland underlying it; inferior internasal suture extending from the nostril to the second supralabial, with a broad underlying gland row. Rostral ovate viewed from above, 2.5 mm in width at its broadest (51% head width), then tapering to a rounded posterior tip. Four supralabial scales, increasing in size from first to last, with the third and fourth nearly equal in size and much larger than the first and second. The first supralabial (not visible in Fig. 5) is overlapped by the prenasal and overlaps the second supralabial. The second supralabial is about twice the size of the first, overlapped by the prenasal, postnasal, and preocular, and overlaps the third supralabial. The third supralabial extends dorsally to the level of the nostril, is overlapped by the preocular and overlaps the ocular and fourth supralabial. The fourth supralabial also extends dorsally to the level of the nostril, and is overlapped by the ocular. There are two postoculars on each side.

The dorsum is covered with brown melanophore pigmentation. On the head, this pigmentation is restricted to the posterior half of the dorsal surface of the rostral (although there is a patch of amber coloration on the rostral at the tip of the snout, apparently a keratinized thickening of the rostral); the prefrontal, frontal, interparietal, supraoculars, and parietals; the dorsalmost apex of the postnasals; the dorsal half of the preoculars; the oculars surrounding the unpigmented eye-window (although only sparsely below the eye on the left); the dorsoanterior apex of the third supralabial on the right; and the dorsal apex of the fourth supralabials. Behind the fourth supralabial, pigmentation in about three transverse rows extends as far laterally as the seventh lateral row on the right, and the sixth row on the left, with a gap of six unpigmented ventral rows. Posterior to this, the body has a brown longitudinal stripe 11 scale rows in width (the middorsal and five scale rows lateral to it on either side), with the scales in the middorsal and four rows lateral to it continuously pigmented for the length of the body, but with scattered unpigmented scales, or groups of scales, occurring in the fifth lateral row. (At the level of the 18th to 22nd middorsals, there is an anomalous irregular transverse band of unpigmented scales, one to three transverse rows in width, that extends to the second lateral row on the right, and completely across the dorsal stripe on the left.) Outside of this stripe, a few pigmented scales are scattered along the sixth lateral row, especially in the vicinity of the vent. The dorsal stripe continues along the length of the tail, 11 rows in width for about the first third of the tail length, then gradually decreases in width along the remaining tail length to include only the middorsal and one row on either side immediately anterior to the terminal scale. The terminal scale is pigmented on its dorsal and lateral surfaces. Other scales on the ventral head, body, and tail lack melanophore pigmentation.

The dorsal stripe is darkest middorsally and gradually becomes lighter laterally due to decreasing pigment density in the scales, especially the posterior portion of the lateralmost rows, and pigmentation is absent in the posterior half of many scales in the fifth row, giving the dorsal stripe an indistinct appearing edge.

The tail decreases in width only slightly over roughly its first half, then tapers more abruptly just before the tail tip; the terminal scale is cone shaped with a sharp, keratinized spine, curved downward to give a slightly hook-like appearance.

Variation. Total length 178–416 mm, middorsal scales 452–472. Tail length appears to be sexually dimorphic. The three male paratypes have tails that have more middorsocaudals and are proportionately longer than that of the holotype and female paratypes (Table 1, Fig. 3). Tail shape, however, does not appreciably differ between the sexes. Postocular number is variable, with four paratypes having two postoculars on both sides of the head, four having three on both sides, and two that each have three on the left and two on the right (Table 1). All specimens have 22 scale rows around the body posterior to the head until just anterior to the tail where the paramidventral scale rows divide five to seven transverse rows anterior to the vent to increase the number of rows around the body to 24 (or 26 in USNM 558302).

The color pattern of all paratypes is similar to that of the holotype. Two specimens (USNM 558307 and 558309, both from Soong Island) differ in having a completely pigmented rostral (rather than having pigmentation limited to the dorsal surface), and pigmentation was more extensive on the head of these two specimens, most notably more extensive pigmentation of the postnasals and preoculars to include all of these scales except the right postnasal of USNM 558309.

Most of the paratypes have a dorsal stripe that is 11 rows in width, as in the holotype, with only scattered pigmented scales in the sixth lateral row. Four specimens (USNM 558303, 558307, 558308, and 558310), however, have more extensive pigmentation in the sixth lateral row, with roughly half or more of the scales lightly pigmented, and with a few scattered pigmented scales occurring in the seventh lateral row. Tail coloration is similar to

the holotype in all paratypes, although unlike the holotype, most specimens have a few pigmented scales in the sev enth lateral row near the vent in addition to an increased frequency of pigmented scales in the sixth lateral row in the vicinity of the vent. In two specimens (USNM 558303 and 558307) pigmentation in the sixth lateral row extends for about half the length of the tail. In the other specimens, the stripe is 11 rows in width for at least half the tail length, with pigmentation in the fifth lateral row either continuing to near the tip or pigmentation in the fourth lateral row continuing to near the tip. Both USNM 558302 and USNM 558305 have a protruded tongue, neither tongue with visible lateral spines. A rectal caecum could not be found in three specimens examined (USNM 558304, 558305, and 558306). Retrocloacal sacs are present in USNM 558302, extending about 7 mm anterior to the level of the vent into the body cavity (2% of the body length). Exposed by dissection of the tail, the left inverted hemipenis of USNM 558302 is straight for its proximal half followed by four coils in its distal half.

Life history note. Although blind snakes are typically regarded as fossorial in habit, Gaulke (1995), Das and Wallach (1998), and Bickford and Wynn (2005) have documented climbing behavior in *Ramphotyphlops*. In addi tion to being collected crawling on the ground and under debris and rocks, as well as in green sea turtle nests, two individuals of *R. hatmaliyeb* were found under circumstances similar to many of the records reported by Das and Wallach (1998) in their review of arboreality in blind snakes. USNM 558302 was observed at night crawling upward in a crease in the trunk of a *Pisonia* tree, about two meters off the ground. Another animal (not collected) was observed about five meters up the trunk of another *Pisonia* tree.

Etymology. "Hatmaliyeb" is one transliteration of the Ulithian name for this snake (likening it to a large worm from Yap), used here as a noun in apposition.

Comparisons

Comparison of *R. adocetus* and *R. hatmaliyeb*. Although similar in appearance, *R. adocetus* and *R. hatmaliyeb* differ in color pattern, relative tail length, and several head features.

All specimens of *R. adocetus* have a dorsal stripe on the body that covers the 13 dorsalmost rows, whereas in *R. hatmaliyeb* the stripe covers 11 rows in most specimens; all *R adocetus* have a dorsal stripe 15 or 17 rows in width on the tail, but in *R. hatmaliyeb* the stripe is 11 or 13 rows in width, reducing in width posteriorly in most speci mens. The rostral scale is entirely pigmented in all specimens of *R. adocetus*, but pigmentation is restricted to the dorsal surface of the rostral in all but two specimens of *R. hatmaliyeb*.

Middorsocaudal number and relative tail length also differ between *R. adocetus* and *R. hatmaliyeb*. Male *R. adocetus* have 27 to 33 middorsocaudal scales and females have 28 to 34, compared to 24 to 27 in the three male *R. hatmaliyeb* and 21 to 23 in females. Male *R. adocetus* have tails 4.5% to 5.5% of total length and females 3.3% to 4.6%, whereas male *R. hatmaliyeb* have tails 3.8% to 4.4% of total length and females 2.9% to 3.6%. Although the relative tail length, but not the middorsocaudal number, appears to be sexually dimorphic in *R. adocetus*, both tail length and middorsocaudal number differ between the sexes in our sample of *R. hatmaliyeb*.

There are also several differences between *R. adocetus* and *R. hatmaliyeb* in head shape and scale pattern. Most specimens of *R. adocetus* have three postoculars on both sides of the head, but *R. hatmaliyeb* is more variable, with both two postoculars and three postoculars occurring in near equal frequency. Viewed from above, the shape of the rostral is pyriform in *R. adocetus* and more ovate in *R. hatmaliyeb*. The rostral in *R. adocetus* tapers more abruptly to its posterior tip, and the lateral free edge of the rostral and its underlying gland row are both concave on the pos terior half. The rostral of *R. hatmaliyeb* tapers posteriorly more evenly, with the converging gland rows straight, not concave, and the free edges of the rostral having only slightly concave lateral edges (Fig. 6). Shape of the anterior head also differs between the species. Both species have heads that are tapered when viewed from above, and wedge-shaped when viewed from the side. In *R. hatmaliyeb*, however, the anteriormost tip of the rostral protrudes anteriorly and slightly ventrally, but does not do so in *R. adocetus*, resulting in a snout that is more pointed in *R. hatmaliyeb* when the head is viewed from above and more angular when viewed from the side (Fig. 6). In addition, the extreme tip of the rostral is darkened in all specimens of *R. hatmaliyeb*. This is most apparent in those speci mens without melanophore pigmention on the anterior rostral, but also noticeable in the two specimens in which the rostral is entirely pigmented. Due to the area's dark amber color, we interpret it to be the result of keratinization of the rostral at its anterior tip.

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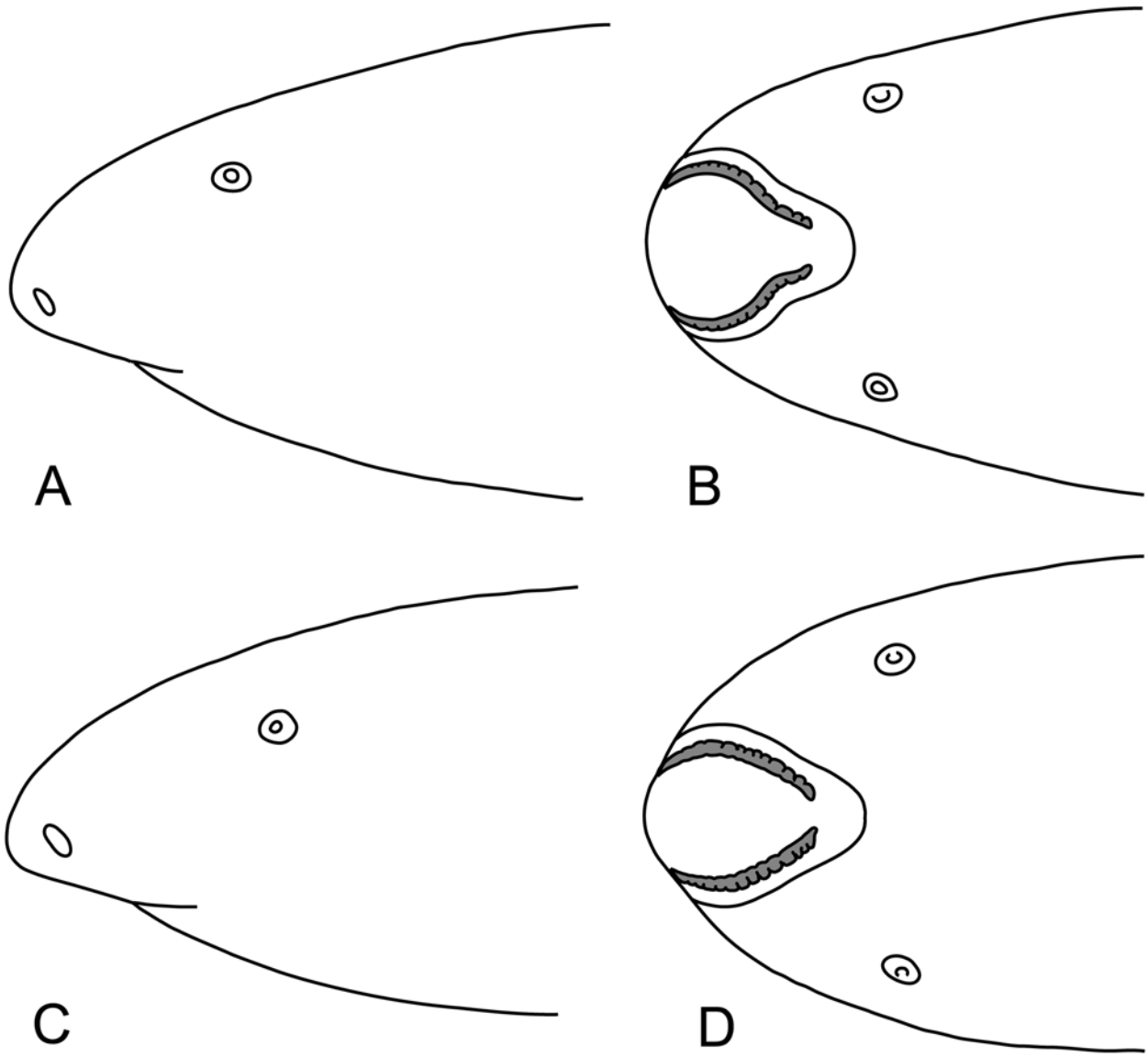

FIGURE 6. Comparison of the head shape and rostral shape of *Ramphotyphlops adocetus* and *R. hatmaliyeb*: (A) left lateral view of *R. adocetus*, USNM 558293, (B) dorsal view of the head of USNM 558293, (C) left lateral view of *R. hatmaliyeb*, USNM 558306, (D) dorsal view of the head of USNM 558306. The rostral free edge is illustrated in B and D, with the underly ing gland row shaded gray.

Comparison of *R. adocetus* and *R. hatmaliyeb* with other species. *Ramphotyhlops adocetus* and *R. hatmali yeb* are superficially similar to members of the *R. flaviventer* complex (*sensu* Wallach 1996). Members of this com plex are also moderately large blind snakes with distinct dorsal stripes, 22 scale rows at midbody, and a similar supralabial scale pattern (Wallach 1996). *Ramphotyphlops acuticaudus* (considered to be a member of the *R. flavi venter* group by McDiarmid *et al.* 1999) is the geographically most proximate blind snake to *R. hatmaliyeb*, occuring in the Palau Islands, about 600 km to the southwest of Ulithi. *Ramphotyphlops acuticaudus* differs from *R. hatmaliyeb* most notably in having a rounded head, viewed from both above and the side, and in having an oval (*sensu* Thomas 1976) rostral shield. In addition, *R. acuticaudus* has 306–393 middorsal scales, compared to 452– 472 in *R. hatmaliyeb*, and a dorsal stripe that contains the middorsal scale and four longitudinal scale rows to either side (for a total of nine), compared to 11 in *R. hatmaliyeb*. *Ramphotyphlops depressus*, with a distribution from the Admiralty Islands southeastward through the Solomon Islands (Wallach 1996), is the geographically closest mem- ber of the *R. flaviventer* complex to *R. adocetus*. It differs from *R. adocetus* in having fewer middorsal scales (289–438 vs. 447–474 in *R. adocetus*) and 24 scale rows around the anterior body in some specimens (Wallach 1996), aswell as having a rounded head when viewed from above and the side, and an oval rostral scale. In addition, *R. acu- ticaudus*, *R. depressus*, and *R. flaviventer* have been shown to have a rectal caecum (McDowell 1974; Wallach 1996; pers. obs.).

In contrast to members of the *R. flaviventer* complex, which have 22 scale rows around the body and a rectal caecum, *R. willeyi* from the Loyalty Islands is the only *Ramphotyphlops* found from the Philippines southeastward

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through New Guinea to the Solomon and Loyalty Islands that is similar to *R. adocetus* and *R. hatmaliyeb* in having 22 scale rows, but without a rectal caecum (McDowell 1974; Shea and Wallach 2000; Wallach 1996). In addition, *R. willeyi* is similar to *R. adocetus* and *R. hatmaliyeb* in having a head that is tapered when viewed from above and a snout shaped like a rounded wedge when viewed from the side, but without a keratinized keel (Boulenger 1900; Shea & Wallach 2000). Shea and Wallach (2000), however, report that *R. willeyi* has 369–375 middorsals, in con trast to 447–474 middorsals in *R. adocetus* and 452–472 in *R. hatmaliyeb*. Boulenger (1900) illustrates an oval or sagittate rostral (*sensu* Thomas 1976) in the holotype (BMNH 1946.1.10.80) of *R. willeyi* (confirmed to be oval by photographic examination of the holotype of *R. willeyi*), and Shea and Wallach (2000) state that NMBA 7088 has an hourglass shaped rostral.

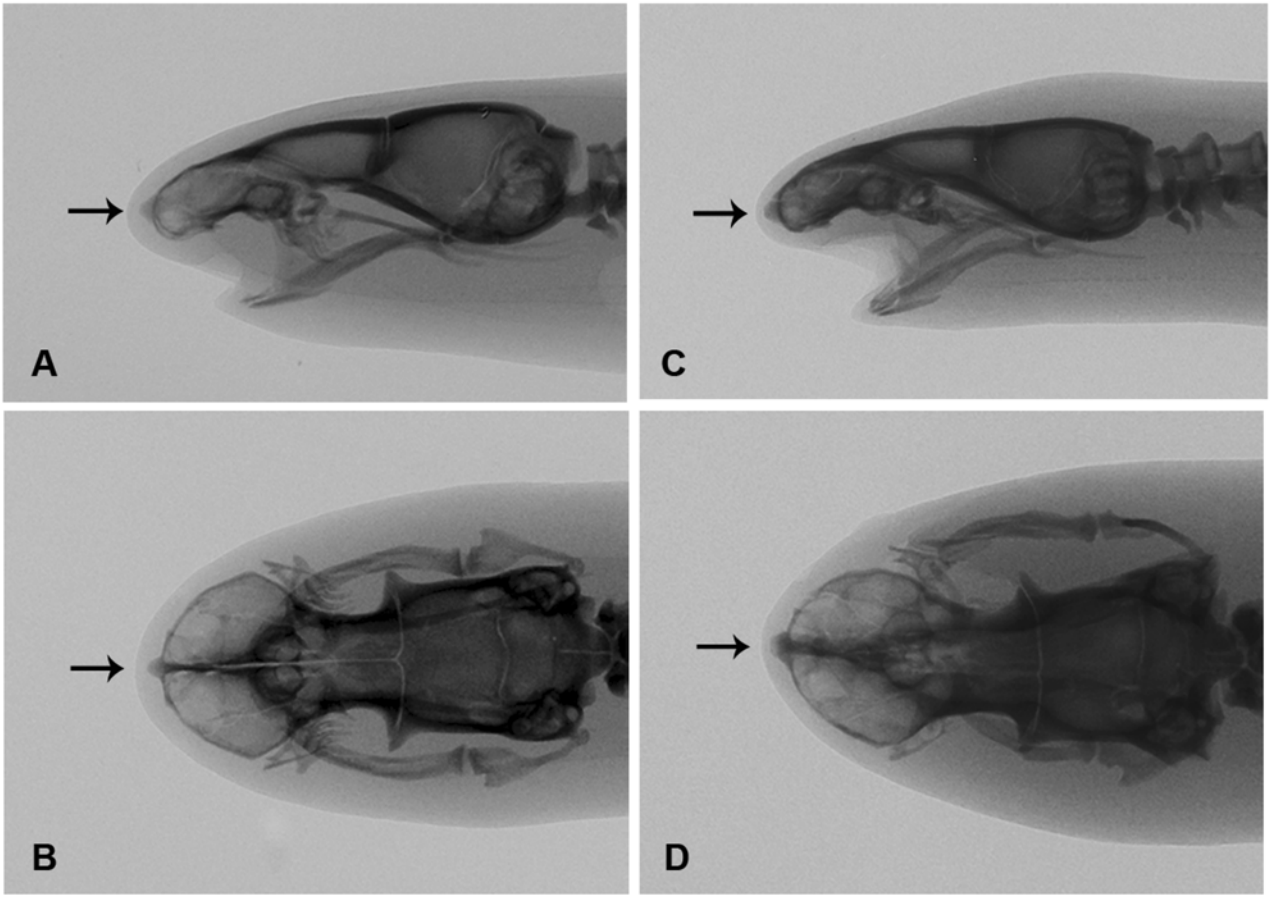

FIGURE 7. Radiographs of the head of *Ramphotyphlops adocetus*: (A) lateral view of USNM 529971, (B) dorsal view of USNM 558296; and the head of *R. hatmaliyeb*: (C) lateral view of USNM 558300, (D) dorsal view of USNM 558303. The arrows indicate the anterior projection of the premaxilla.

Both *R. adocetus* and *R. hatmaliyeb* also have an anteriorly directed, cone-shaped projection of the premaxilla at the tip of the head (Fig. 7). This projection appears to underlie the dark amber-colored area at the anterior tip of the rostral in *R. hatmaliyeb*. In several specimens of *R. adocetus* the projection appears to underlie a circular area at the tip of the rostral in which melanophore pigmentation is reduced or absent. Although knowledge of blind snake osteology is largely limited to the 13 skulls illustrated in List (1966), such a projection has not been reported before in blind snakes.

Discussion

Ant Atoll is located in the eastern Caroline Islands (Federated States of Micronesia), ca. 15 km southwest of Pohn pei, the nearest high island. The atoll is about 40 km in circumference and 7 to 11 km in diameter. Eleven of the twelve islands in the atoll are distributed along the southeastern and eastern side of the atoll, with Wolouna (the remaining island) isolated on the atoll's northwestern side. With the exception of Wolouna, and excluding a deep water passage between Imwinyap and Nikalap Aru, the islands are separated by shallow (easily wadeable) gaps from a few meters wide to about 1.5 km between Pasa and Nikalap Aru. Total land area is 1.87 km^2, with the two largest islands, Pamuk (0.6 km^2) and Nikalap Aru (0.5 km^2) accounting for over half of the land. Pasa, on which all

specimens were collected, has an area of only 0.2 km^2. The highest elevation on the atoll is about 3–4 m above sea level. Specimens of *R. adocetus* have been found only on Pasa Island, although all 12 islands in the atoll have been searched (Buden and Panuel 2010).

Vegetation on Ant Atoll consists largely of coconut (*Cocos nucifera*) forest. Other common trees contributing to the nearly closed canopy include *Artocarpus altilis*, *Barringtonia asiatica*, *Cordia subcordata*, *Ficus* spp., *Guettarda speciosa*, *Hernandia sonora*, and *Pisonia grandis*. Young palms and ferns contribute to the ground cover and the soil is largely sand and gravel with scattered coral rock, with little or moderate accumulations of organic matter. Pits for cultivating taro (*Cyrtosperma chamissonis*) have been excavated in the interior of the larger islands, but are now out of use.

Ulithi is located in the western Caroline Islands (Federated States of Micronesia), about 610 km northeast of Palau and about 2040 km west of Ant Atoll. It is approximately 170 km northeast of Yap, the nearest high island. Ulithi consists of a main atoll of 36 islands (including Dorooleng, Piig, and Soong islands), a largely submerged atoll with two islands (Giilab and Iaar) to the east, and a string of three islands (L'oosiyep, Bulbul, and Yeew) lying within their own reef between Giilab and Iaar, and the main atoll of Ulithi.

The main atoll is about 100 km in circumference and 6 to 34 km in diameter. Dorooleng is located near the northwestern tip of the atoll, Soong is on the west side six km to the southeast of Dorooleng, and Piig Island is located at the southern tip of the atoll, about 25 km southeast of Soong Island. Bulbul lies about 15 km east of the main atoll (and about 23 km east and northeast, respectively, of both Soong and Piig islands). Iaar and Giilab islands lie about eight and nine km (respectively) to the east and northeast of Bulbul Island. The islands where *R. hatmaliyeb* has been collected range from 0.05 to 0.16 km^2 in area (Bryan 1971) and are only a few meters above sea level.

The vegetation of the islands where *R. hatmaliyeb* has been found includes beach strand where *Argusia (Tournefortia) argentea* is dominant, with varying levels of atoll forest and coconut thickets. On larger islands, *Guettarda speciosa*, *Pandanus tectarius*, or *Pipturus argenteus* are abundant in some coastal areas, transitioning to thickets of *Cocos nucifera* and atoll forest with *Pisonia grandis* dominant, but also *Barringtonia asiatica*, *Ficus* spp., *Eugenia* sp., and, on some islands, *Neisosperma oppositifolia*. *Aidia cochinensis*, *Crataeva speciosa*, and *Morinda citrifolia* are often in the understory. More extensive areas of tall *B. asiatica* forest and two small areas of *Bruguiera gymnorrhiza* mangroves occur on Soong Island. The substrate of the islands is typically sand in leeward beach strand areas, and sand and coral mixed with loam derived from fallen leaves and bird droppings in the inte rior of the islands, becoming rockier on seaward and eroded coasts. Soong Island is mostly rocky with less soil.

Such low-lying atolls as Ant and Ulithi are usually inhabited by widespread, vagile species. For example, excepting *Ramphotyphlops adocetus*, the terrestrial vertebrate fauna of Ant Atoll is a subset of more broadly dis tributed species also occurring on Pohnpei, and the reptiles found on Ant Atoll are all species that are found widely in the Caroline Islands and beyond (Buden 1996). Aside from the two new species of *Ramphotyphlops*, the only reptiles known solely from atolls in the Caroline Islands east of Palau are the geckos *Perochirus scutellatus*, known only from Kapingamarangi Atoll (Buden 1998); *P.* cf. *scutellatus* from Ulithi on Sorenleng (Dorooleng) Island (Wiles [2004]) and Bulbul, Giilab, Iaar, Soong, and Yeew islands (Falanruw, pers. obs.); and *Lepidodactylus oli goporus*, known from only a single island on Namoluk Atoll (Buden 2007).

Pacific atolls, in the form of unconsolidated sand and gravel perched on an emergent paleoreef, are recent phe nomena, only one to two thousand years old, but built upon the rims of karst platforms that were exposed when sea levels were as much as 125 m lower during the peak of the last glaciation (Dickinson 2004). Today's atolls formed only after present sea levels were reached following sea level lowering of 1.0 to 2.6 m about two thousand years ago, although ephemeral cays may have existed on submerged coral reef flats standing upon these submerged plat form rims prior to this reduction in sea level (Dickinson 2004). If *R. adocetus* and *R. hatmaliyeb* require stable, perched atolls for habitat, then they must have dispersed to Ant Atoll and Ulithi no more than two thousand years ago. The relatively close high islands of Pohnpei and Yap, respectively, are appealing potential sources for *R. ado cetus* on Ant Atoll and *R. hatmaliyeb* on Ulithi, but the apparent absence of *R. adocetus* on Pohnpei and *R. hatmal iyeb* on Yap is problematic for this explanation, especially for Pohnpei, which has a well documented reptile fauna composed of species that are widespread in Micronesia, with many also widely distributed in Oceania (Buden 2000). Of 18 known species of terrestrial reptile on Pohnpei, only a lizard (*Emoia ponapea*) is endemic, and the only known snake is the widespread *R. braminus* (Buden 2000). Alternately, *R. adocetus* and *R. hatmaliyeb* could have existed on the original karst platforms and adapted to ephemeral cays built upon submerged reefs during the Holocene highstand, passing through this phase of atoll formation before more stable perched atolls formed follow ing late Holocene sea level lowering. Such a transition could have occurred repeatedly during Pleistocene glacial interglacial cycles, allowing the possibility that *R. adocetus* and *R. hatmaliyeb* could be relic populations of species

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that evolved *in situ* in the Caroline Islands (Dickinson pers. com.).

Pregill (1998) reported on the presence of blind snake vertebrae, in strata believed to be prehuman, from Agu iguan and Tinian islands in the Mariana Islands. Although interpreted to be *R. braminus* by Pregill, this identifica tion is doubtful if these vertebrae are prehuman as thought, and more likely represent the past presence of an unknown blind snake in the Marianas. Watling *et al.* (2010) have recently confirmed an earlier report (Anonymous 1898) of *Ramphotyphlops* in the Fiji Islands, and small snakes, possibly *R. hatmaliyeb*, or another undescribed spe cies of blind snake, have been reported by local residents (pers. com. to Falanruw) from Ngulu Atoll, about 110 km southwest of Yap. Although the presence of *R. adocetus* on Ant Atoll and *R. hatmaliyeb* on Ulithi is unexpected and difficult to explain, their discovery and these other occurrences document a wider distribution of blind snakes in the western Pacific than previously believed.

Conservation considerations. *Ramphotyphlops adocetus* and *R. hatmaliyeb* are both vulnerable to extinction because of their limited known distributions, each restricted to a small Pacific atoll. A variety of anthropogenic influences including habitat loss and the introduction of invasive animals pose possible threats.

Ramphotyphlops adocetus may be particularly vulnerable. Although Ant Atoll is comprised of 12 islands, *R. adocetus* has been found only on Pasa Island. Rats, domesticated cats, and domesticated pigs are documented from the atoll (Buden 1996), and it is particularly noteworthy that Pasa is one of only two islands in the atoll on which rats (*Rattus exulans* and *R.* cf. *tanezumi*) are not present (Buden and Panuel 2010).

In addition to the six islands on Ulithi from which we report *R. hatmaliyeb*, it is known by Ulithians to also occur on Yeew, but it has not been found on L'oosiyep Island, the largest island in the group that also includes Bul bul and Yeew. Unlike the other islands where *R. hatmaliyeb* has been found, L'oosiyep has introduced monitor liz ards, chickens, rats, and pigs, suggesting that these introduced species have greatly reduced or extirpated *R. hatmaliyeb* on L'oosiyep, and possibly on other islands with such introduced predators.

These vulnerabilities on Ant Atoll and Ulithi are common on many Pacific islands (Fritts and Rodda 1998). Conservation measures should be directed at limiting habitat loss and preventing the spread of invasive animals on the islands where these species are currently known.

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APPENDIX: Additional material examined.

Ramphotyphlops acuticaudus: USNM 207024, 207026–207028, 558277–558282, Palau Islands, Koror; USNM 558274–558276, Palau Islands, Babelthuap.
Ramphotyphlops willeyi (photograph): BMNH 1946.1.10.80.

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