HERPETOZOA 23 (3/4): 31 - 43
Wien, 30. Jänner 2011

Natural history, potential distribution and conservation status of the Manabi Hognose Pitviper *Porthidium arcosae* (SCHÄTTI & KRAMER, 1993), in Ecuador

(Squamata: Viperidae: Crotalinae)

Naturgeschichte, potentielle Verbreitung und Schutzstatus der Lanzenotter *Porthidium arcosae* (SCHÄTTI & KRAMER, 1993) in Ecuador
(Squamata: Viperidae: Crotalinae)

JORGE H. VALENCIA & GEORGE VACA-GUERRERO & KATTY GARZON

KURZFASSUNG

Porthidium arcosae (SCHÄTTI & KRAMER, 1993) ist eine terrestrische, kleinwüchsige (ca. 720 mm Gesamtlänge), seltene und wenig erforschte Grubenotter, die als Endemit von Ecuador in Trockenwaldhabitaten der Provinz Manabí vorkommt. Aus Untersuchungen an Sammlungsexemplaren und Freilandbeobachtungen ergaben sich neue Erkenntnisse zur Naturgeschichte und potentiellen Verbreitung. Die vorliegende Aktualisierung der Kenntnis der horizontalen und vertikalen Verbreitung schließt 12 Fundorte in der Provinz Manabí ein. Eine ökologische Nischenmodellierung sagte weitere küstennahe Vorkommen in den Provinzen Manabí (nördlich bis San Vicente, 50 km nördlicher als bekannt) und Santa Elena voraus. Sexualdimorphismus bei Rumpf- oder Schwanzlänge war nicht nachweisbar, jedoch in der relativen Kopfbreite, wobei Weibchen signifikant breitere Köpfe hatten. Das Paarungsverhalten wird an drei Gruppen gehälterter Tiere beschrieben. *Porthidium arcosae* ernährt sich als Jungtier von Echsen, erwachsen von Nagetieren. Vier weitere Grubenotternarten leben mit *P. arcosae* sympatrisch: *Bothrops asper*, *Bothrops punctatus*, *Bothriechis schlegelii* und *Porthidium nasutum*. Der Fall eines Giftbisses durch *P. arcosae* an einem 29-jährigen Mann wird beschrieben. Bei Abschätzung des Schutzstatus wäre *P. arcosae* in die IUCN Kategorie 'Endangered' einzustufen.

ABSTRACT

Porthidium arcosae (SCHÄTTI & KRAMER, 1993) is a terrestrial, small-sized (ca. 720 mm total length), rare and little studied pitviper endemic to Ecuador, occurring in a variety of dry xeric forests, in the province of Manabí. Specimens preserved in collections and observations of snakes in captive conditions yielded new information about its natural history and potential distribution. The present update of our knowledge on the geographical and altitudinal range includes 12 localities in the province of Manabí. An ecological niche model predicted additional records along the coast of the provinces of Manabí (as far to the north as San Vicente, about 50 km beyond the known territory) and Santa Elena. Sexual dimorphism was not significant relative to the length of body and tail. However, there was a significant difference in the length-to-width ratio of the head, which is comparatively wider in females. Courtship and mating is briefly described from three captive groups. *Porthidium arcosae* feeds on lizards in its juvenile phase and rodents as an adult. Four more pitviper species are sympatric with *P. arcosae*: *Bothrops asper*, *Bothrops punctatus*, *Bothriechis schlegelii* and *Porthidium nasutum*. A case is reported of envenomation of a 29-year-old man from a bite by *P. arcosae* is reported. A conservation status assessment indicates that *P. arcosae* would classify for the IUCN category Endangered (EN).

KEY WORDS

Squamata: Viperidae: Crotalinae: *Porthidium arcosae*, natural history, size, sexual dimorphism, habitat, microhabitat, activity patterns, prey, abundance, longevity, human envenomation, sympatry, mimicry, predatory behavior, conservation status, dry forest, endemic species, ecological niche modeling, province of Manabí, Ecuador

INTRODUCTION

Lanceheads of the genus *Porthidium* COPE, 1871, are distributed from Mexico in Central America to the Neotropical region of Venezuela, Colombia and Ecuador (CAMPBELL & LAMAR 2004). From Ecuador, two species are reported: *Porthidium nasutum* (BOCOURT, 1861) in the lowlands of the pacific versant, and *P. arcosae* (SCHÄTTI &

Kramer, 1993), in the coastal Province of Manabí (Almendáriz 1991; Campbell & Lamar 2004; Coloma 2004). Both species lack detailed biological studies as compared to other members of the ophidian fauna from Ecuador (Cadle 1985; Cisneros-Heredia et al. 2006). Since its recent discovery by Schätti & Kramer (1993) limited attention was payed to *P. arcosae*, and information concerning its distribution and natural history is fragmentary. The present research which is largely based on information retrieved from a database of Fundación Herpetológica Gustavo Orcés, Quito, Ecuador (FHGO), aims to update information on the natural history, geographic distribution and conservation status of the pitviper *P. arcosae* in Ecuador.

MATERIALS AND METHODS

Field data (date, time, locality, habitat and abundance) was gathered in various localities in the Province of Manabí by using personal experience encounter surveys and from specimens collected by native people. Ten individuals of *P. arcosae* were maintained under captive conditions at the Vivarium de Quito to analyze their reproductive and predatory behavior, whereas, voucher specimens (n = 22) were preserved and deposited in the Fundación Herpetológica Gustavo Orcés, Quito, Ecuador (FHGO).

Ecological data was obtained from 12 localities where the snake was found and from which geographic coordinates were known (four localities registered in the database of FHGO were known only by their names and geographic coordinates were impossible to verify). Twenty-six preserved specimens were dissected, and their stomach contents and reproductive status analyzed. Clinical reports in medical units of the Province of Manabí about patients bitten by venomous snakes were reviewed as well. A digital scale was used to weigh the animals (to the nearest 0.1 g). Morphometric data was obtained from six adult females and nine adult males. Measurements of the head were made using a digital caliper (to the nearest 0.1 mm), and measurements of the body by means of a metal ruler. All morphometric values were expressed as mean ± standard deviation; Table 1 summarizes this specimens' data.

The geographic coordinates and elevations were taken from the FHGO database system, according to the physical map of the Republic of Ecuador 1:250.000, published by the IGM - Instituto Geográfico Militar of Ecuador (2008).

Abbreviations used: FHGO - Fundación Herpetológica Gustavo Orcés, Quito; MNP - Machalilla National Park, Manabí, Ecuador; IUCN - The International Union for the Conservation of Nature; SVL - snout-vent length; TL - tail length (from the vent to tip of tail); TTL - total length (from tip of snout to tip of tail); HL - head length; HW - head width; EN - Endangered.

Environmental layers and distribution model building

A total of 16 record localities were retrieved from the FHGO Database, which included collection data of animals kept alive. Due to the fact that four localities from Jipijapa district could not be verified geographically, the ecological niche modeling was based on 12 collection localities only.

Accuracy of georeferences was estimated following the best practices stated by Chapman & Wieczorek (2006) and using the 'Georeferencing Calculator' (Wieczorek 2001).

Nineteen environmental layers (resolution: 1 km) were obtained from WORLDCLIM (Hijmans et al. 2005). Highly correlated variables ($r^2 > 0.85$) were removed by constructing a global correlation tree (within 19 bioclimatic variables from Ecuador) using the UPMGA method in BioMapper 4.0 (Hirzel et al. 2007). Data reduction resulted in ten non-redundant environmental variables: 'annual mean temperature', 'mean monthly temperature range', 'isothermality' (= temperature mean diurnal range / temperature annual range), 'mean temperature of wettest quarter', 'annual precipitation', 'precipitation seasonality', 'precipitation of

wettest quarter', 'precipitation of driest quarter', 'precipitation of warmest quarter', and precipitation of coldest quarter'.

Ecological niche models were generated with a presence-only method based on a maximum entropy approach (Maxent; PHILLIPS et al. 2006) that was shown to be effective for modeling species' distributions in comparison with alternative approaches (see ELITH et al. 2006). Default recommended values were used for the convergence threshold (10^{-5}) and maximum number of iterations (500).

The predictive performance of the ecological niche model of *P. arcosae* was assessed by the statistic means based on a Jackknife cross-validation, 'Leave-One-Out', used for testing models when locality records are scarce (PEARSON et al. 2007). Since Maxent output is continuous, a threshold must be selected to create a binary distribution model. A conservative threshold was chosen based on the lowest predicted value associated with any of the observed sampling sites for the model (PEARSON et. al. 2007; LPT - lowest presence threshold).

Thus, the final ecological niche model was sectioned according to analogous vegetation systems in which *P. arcosae* was reported, Cloud Forest and Evergreen Foothill Forest vegetation systems being removed.

RESULTS

Distribution

Porthidium arcosae (Fig. 1) was recently reported by SCHÄTTI & KRAMER (1993), COLOMA et al. (2000), and CAMPBELL & LAMAR (2004), as a species restricted to dry forest in western Ecuador (Dry Scrubland of Lowlands, see SIERRA 1999).

Retrieval from the FHGO database resulted in the following list of record localities: in the Province of Manabí, the presence of *P. arcosae* was recorded from three localities of the Puerto López district (Agua Blanca, Salango, and Machalilla); six of the Jipijapa district (La Cuesta, Naranjal, Sancan, San Eloy, Santa Rosa, and San Sebastián); one locality of the Manta district (San Mateo); one of the Montecristi district; and one from Sucre (Bahía de Caráquez), which corresponds to the northernmost record of this species. The known distribution area of *P. arcosae* covers about 3900 km^2; the altitudinal range is from sea level to ca. 300 m a.s.l. (Fig. 2, Table 1).

The ecological niche model of *P. arcosae* predicted unknown presence areas along the northern coast of Manabí (Jama, Cabuyal, Canoa, and San Vicente localities), about 50 km from the northernmost known occurrence. Southern predicted regions were approximately 60 km from the southernmost known site of occurrence. This latter area extends along the coastal region into the Province of Santa Elena.

Habitat, microhabitat and activity patterns

All records of *P. arcosae* originated from dry forests of the coastal and central-western regions in the Province of Manabí, which include the vegetative systems 'Deciduous Coastal Lowland Forest', 'Semideciduous Coastal Lowland Forest', 'Dry Scrub Coastal Lowland Forest', and 'Scrubby Savannah' (see SIERRA 1999). BARRAGÁN et al. (2001) reported the presence of this snake in primary and secondary forest, occasionally in open areas, and urbanized landscape.

The terrestrial viper's activity was primarily nocturnal (17:20 - 21:48; n = 27 observations), however, active individuals were also observed by day (8:00 - 13:30; n = 3). During the daytime, the temperature in the dry forest became very high (> 30 ºC), and *P. arcosae* remained underground in the sampling season (March to June 2001). But on clear days in the short periods of heavy precipitation (February-April), these pitvipers emerged from their hideouts (09:30 - 10:30; n = 8) and moved on the ground in continuous zig-zag locomotion, which was clearly supported by the short and strong tail.

Fig. 1: *Porthidium arcosae* (Schätti & Kramer, 1993) from San Mateo, Manta, Province of Manabí, Ecuador (FHGO live coll. 2160). Photo: Jorge H. Valencia.

Abb. 1: *Porthidium arcosae* (Schätti & Kramer, 1993) aus San Mateo, Manta, Provinz Manabí, Ecuador (FHGO 2160, Lebendtiersammlung). Photo: Jorge H. Valencia.

Size and sexual dimorphism of adult individuals

Mean total length (TTL) of six adult female specimens was 626.8 ± 81.7 mm (range 495.0 – 726.0 mm) and of nine adult males 575.7 ± 83.8 mm (range 412.0 – 690.0 mm). The maximum TTL of 726.0 mm was observed in a female (FHGO living collection 2473). The maximum body mass found was 547 g in the female FHGO living collection 2472.

The differences in total length (TTL) between males and females were not significant (one-way ANOVA $F = 1.37$, $p > 0.26$). The tail length (TL) and the proportion TL/TTL were compared between female and male adult specimens. In both above traits, significant differences among sexes were also not found (one-way ANOVA; $F = 1.55$, $p > 0.23$ TL; $F = 3.41$, $p > 0.08$ TL/TTL).

The proportion of head length (HL) and head width (HW) revealed significant sexual differences between adult specimens; female heads were proportionately wider than male heads (one-way ANOVA $F = 9.03$, $p = 0.01$) (Fig. 3).

Courtship and mating

No field observations of copulation or courting of *P. arcosae* were available from the literature. Below are the summarized (largely anecdotal, not statistically supported) observations made under captive conditions, in three groups, of these pitvipers consisting of two males and a female each.

1) In the initial reconnaissance and combat phase, we observed combat preludes between males with repetitive tongue moves which lasted 2 - 3 seconds with intervals of 1 - 2 seconds, during 20 ± 7 minutes. This activity between males was followed by

Table 1: Thirty-two specimens of *Porthidium arcosae* (Schätti & Kramer, 1993) originating from the Province of Manabí, Ecuador, were available for the present study. FHGO - Inventory number of Fundación Herpetológica Gustavo Orcés, Quito, Ecuador; DC – Date of Collection; sex (M – Male, F – Female); BM – Body Mass [g]; SVL – Snout Vent Length [mm]; TTL – Total Length [mm]; HL – Head Length [mm]; HW – Head Width [mm]; P/A – Preserved (P) / Alive (A); SC - Stomach Contents present (+) / absent (-).

Tab.1: Die zur vorliegenden Untersuchung verwendeten zweiunddreißig Exemplare von *Porthidium arcosae* (Schätti & Kramer, 1993) aus der Provinz Manabí, Ecuador. FHGO - Inventarnummer der Fundación Herpetológica Gustavo Orcés, Quito, Ecuador; DC – Sammeldatum; Sex - Geschlecht (M - Männchen, F – Weibchen); BM – Körpermasse [g]; SVL – Kopf-Rumpf-Länge [mm]; TTL – Gesamtlänge [mm]; HL – Kopflänge [mm]; HW – Kopfbreite [mm]; P/A – Konserviert (P) / Lebend (A); SC - Mageninhalt vorhanden (+) / fehlend (-).

FHGO	Locality, Altitude / Fundort, Seehöhe	DC	Sex (M/F)	BM [g]	SVL [mm]	TTL [mm]	HL [mm]	HW [mm]	P/A	SC (+/-)
2160	San Mateo, Manta	17.09.1998	F	50.6	559	660	33.6	22.9	A	-
3982	San Mateo, Manta	16.09.1998	F	53.1	539	600	30.1	20.3	P	-
2521	San Mateo, Manta	04.04.2002	M	47.3	460	528	27.5	19.7	A	-
3615	Montecristi	17.09.1998	M	103.8	507	566	29.0	17.0	P	+
3005	Jipijapa, La Cuesta	20.04.2001	F	10.0	266	298	18.5	8.5	P	+
3119	Jipijapa, La Cuesta	20.04.2001	M	10.0	251	270	17.5	11.7	P	+
3154	Jipijapa, La Cuesta	26.05.2001	M	13.2	266	300	17.8	10.1	P	-
3164	Jipijapa, La Cuesta	28.05.2001	F	175.8	439	495	32.8	18.0	P	-
3210	Jipijapa, La Cuesta	23.05.2001	F	78.2	269	253	16.6	9.5	P	-
3111	Jipijapa, Piedras Pintadas	24.04.2001	M	12.0	226	260	17.6	9.6	P	-
3118	Jipijapa, Piedras Pintadas	20.04.2001	M	10.0	243	270	18.5	8.5	P	+
2286	Montecristi	17.11.2002	F	97.9	321	358	17.9	12.0	A	-
3122	Jipijapa, Piedras Pintadas	20.04.2001	M	12.0	249	280	19.0	9.0	P	-
3150	Jipijapa, Piedras Pintadas	16.05.2001	F	102.2	219	243	16.5	10.5	P	-
3239	Jipijapa, Piedras Pintadas	18.05.2001	M	16.0	214	245	16.4	7.6	P	-
3133	Jipijapa, San Sebastián	20.04.2001	M	12.0	614	690	38.1	18.1	P	-
2718	Jipijapa, Los Laureles	11.04.2001	M	28.0	191	215	14.8	10.6	P	-
3123	Jipijapa, Los Laureles	25.04.2001	F	8.0	223	265	16.7	11.4	P	+
2490	Jipijapa, Los Laureles	17.05.2001	M	146.0	518	590	28.6	17.1	A	-
3559	Jipijapa, Naranjal	20.05.2001	M	56.0	221	248	17.9	10.0	P	-
3186	Jipijapa, Pepito Colorado	26.05.2001	M	301.5	547	615	30.7	18.2	P	+
3212	Jipijapa, Pepito Colorado	22.05.2001	F	28.0	238	240	16.6	10.6	P	-
2463	Jipijapa, Piedras Pintadas	19.04.2001	F	156.0	552	620	32.1	17.3	A	-
2462	Jipijapa, Los Laureles	06.04.2001	M	40.0	376	420	21.5	12.6	A	-
2489	Jipijapa, Piedras Pintadas	17.05.2001	M	288.0	577	620	33.1	18.5	A	-
3566	Jipijapa, Pisloy Central	12.04.2001	M	315.0	440	507	29.7	13.5	P	-
3439	Jipijapa, Sancón	16.06.2001	F	42.3	213	237	16.0	11.3	P	-
3167	Jipijapa, San Eloy	22.04.2001	M	230.0	559	620	25.4	16.0	P	+
2472	Jipijapa, Santa Rosa	22.04.2001	F	547.0	628	700	40.1	27.9	A	-
2473	Jipijapa, Santa Rosa	05.05.2001	F	422.0	663	726	36.2	23.1	A	-
2487	Jipijapa, Los Laureles	19.05.2001	M	38.0	241	271	17.1	7.8	A	-
3777	Parque Nacional Machalilla, Salango	15.06.2003	M	299.0	569	629	34.5	16.0	P	+

swift moves, pulsative movements of the head and circular movements of the body; at times, occasional circular movements around the female occurred. Duration of these movements was 10 - 43 minutes separated by intervals of decreased activity.

2) In the courtship phase, the males showed their interest in females by seeking close encounters with the female for periods of 6 – 8 minutes. In these periods, the male's head was positioned above the female's head for a while and the first quarter of the male's body over the anterior portion of the female's body without making contact, except through the male's constant tongue movements. In the end, both individuals separated from each other. After a ritual combat one of the males began to make circular movements around the body of the female for 12 minutes, then slid back and placed its head on the female's head with pulsative moves. After that it tilted away for 15 minutes. In the following 7 minutes, the male climbed the body of the female and after this the pair joined their tails for the next 12 minutes.

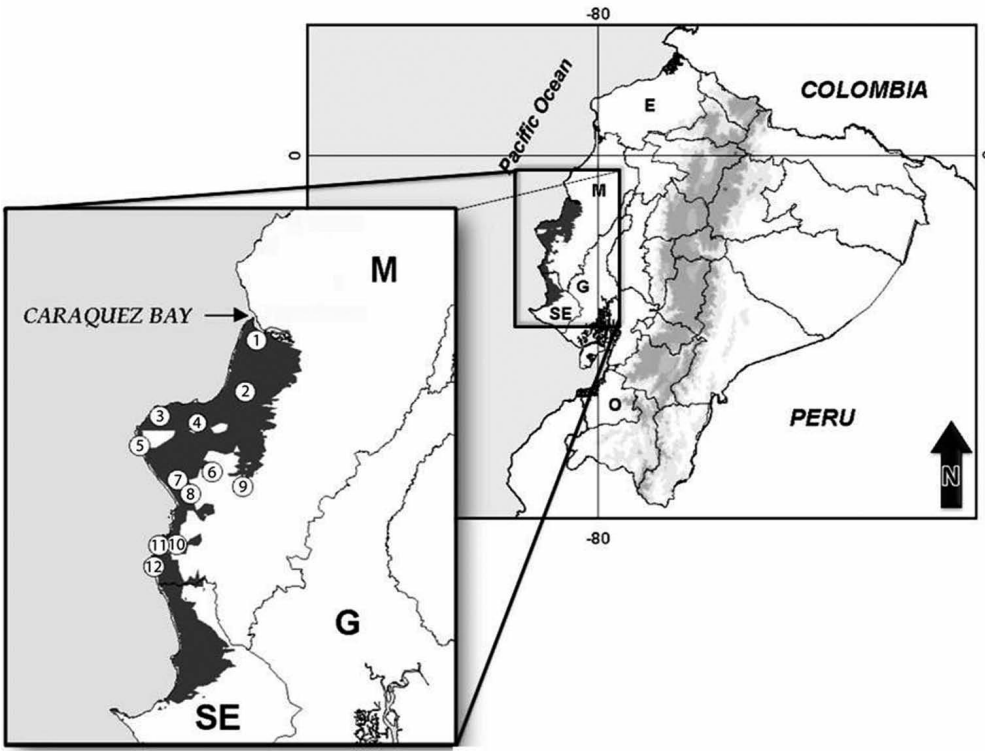

Fig. 2: Distribution of *Porthidium arcosae* (Schätti & Kramer, 1993) in western Ecuador. Potential range area of *P. arcosae* (dark gray); physical records of *P. arcosae* are numbered (1-12); the western provinces (E - Esmeraldas, M - Manabí, SE - Santa Elena, G - Guayas, O - El Oro). Record localities: 1 - Bahía de Caráquez, 2 - San Eloy, 3 - San Mateo, 4 - Montecristi, 5 - Santa Rosa, 6 - Sancán, 7 - Naranjal, 8 - La Cuesta, 9 - Pisloy, 10 - Agua Blanca, 11 - Puerto López, 12 - Machalilla.

Abb. 2: Verbreitung von *Porthidium arcosae* (Schätti & Kramer, 1993) in West-Ecuador. Potentielle Verbreitung von *P. arcosae* (dunkelgrau), Nachweise von *P. arcosae* sind numeriert (1-12); die westlichen Provinzen (E - Esmeraldas, M - Manabí, SE - Santa Elena, G - Guayas, O - El Oro). Fundortlegende: 1 - Bahía de Caráquez, 2 - San Eloy, 3 - San Mateo, 4 - Montecristi, 5 - Santa Rosa, 6 - Sancán, 7 - Naranjal, 8 - La Cuesta, 9 - Pisloy, 10 - Agua Blanca, 11 - Puerto López, 12 - Machalilla.

3) The mating phase lasted 2 hours and 24 minutes, and included the joining of tails and the introduction of one hemipenis into the sexual cavity of the female. Gestation after mating under captive conditions was not observed.

Prey and predatory behavior

During field observations (mainly nocturnal), *P. arcosae* was never seen capturing prey. Nevertheless, remains of the following items (SVL indicated) were found in the gastrointestinal tracts of preserved adult individuals: an adult rodent *Heteromys* sp. (FHGO 3186; SVL 64 mm), the teiid lizard *Ameiva septemlineata* Duméril, 1851 (FHGO 3615, 3167; SVL 26.6 mm and 35.8 mm, respectively), an unidentified rodent (FHGO 3777; SVL 62.6 mm), and the iguanian lizard *Microlophus occipitalis* (Peters, 1871) in four snake specimens (FHGO 3118, 3119, 3123, 3005; SVL 27.0 - 29.8 mm). Eight snakes out of 26 dissected

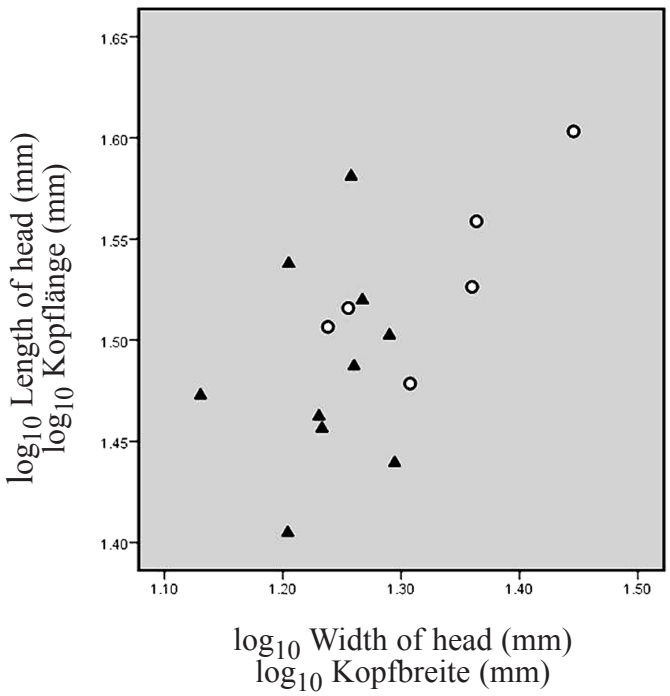

Fig. 3: Head length versus head width in 6 adult female (○) and 9 adult male (▲) *Porthidium arcosae* (SCHÄTTI & KRAMER, 1993) from western Ecuador. The proportionately wider head of the females represents a clear sexual dimorphism.

Abb 3: Kopflänge und Kopfbreite bei 6 erwachsenen Weibchen (○) und 9 erwachsenen Männchen (▲) von *Porthidium arcosae* (SCHÄTTI & KRAMER, 1993) aus West-Ecuador. Die relativ größere Kopfbreite der Weibchen stellt einen deutlichen Geschlechtsdimorphismus dar.

revealed stomach contents, however, one item at most.

The predatory behavior in this species is similar to other pitvipers, involving pulsative moves of the head and rapid tongue movements towards the prey. The attack is quick and takes between 6 to 30 seconds before biting the prey, which is released immediately after the bite. In wild and captive conditions, coiling around the prey was not observed.

Sympatric snakes and similar species

Porthidium arcosae is an Ecuadorian endemic snake known only from the western lowlands of the Provinces of Manabí and, supposedly, Santa Elena, where it occurs in sympatry with four pitviper species: *Bothrops asper* (GARMAN, 1884), *Bothrops punctatus* (GARCIA, 1896), *Bothriechis schlegelii* (BERTHOLD, 1846) and *Porthidium nasutum*.

Within the range area of *P. arcosae*, the vegetative composition changes abruptly with the altitude. Here, toward coastal areas, the wet forest of the ridgetops rapidly turns into the dry forest of the middle and lower slopes below 300 m a.s.l. CISNEROS-HEREDIA & YÁNEZ-MUÑOZ (2005) reported the occurrence of *P. nasutum* in the Machalilla National Park up to 750 m a.s.l. (Cerro San Sebastián), along the foothill evergreen forest and low montane forest. The proximity between these two species in the MNP may cause confusion to differenti-

ate them, particularly in juvenile and subadult stages. *Porthidium nasutum* can be confused with *P. arcosae* because of similar color-pattern with a pale vertebral line; on either side of this line may be triangular and rectangular blotches.

Porthidium nasutum can be differentiated from *P. arcosae* by fewer ventrals: 123-145 versus 159-168 (counts of *P. nasutum* in Campbell & Lamar 2004, of *P. arcosae* from FHGO sample). *Bothrops asper* and *B. punctatus* (first record in dry forest) are larger species (maximum TTL 250 cm and 112 cm, respectively; versus 76 cm), whose features differ by coloration pattern.

Barragán et al. (2001) reported the presence of other snake species in the same area in which *P. arcosae* was found. These species are *Boa constrictor imperator* Daudin, 1803, *Atractus* sp., *Dipsas oreas* Cope, 1868, *Imantodes cenchoa* (Linnaeus, 1758), and *Leptodeira septentrionalis* (Kennicott in Baird, 1859).

Resemblance in some colubrid snakes with *P. arcosae* may be regarded as mimicry, similar to other viperids in the Neotropical region (Sazima 1992; Brodie & Brodie 1994). *Atractus* sp., *Dipsas oreas* and *Leptodeira septentrionalis* are nocturnal, terrestrial (*Atractus* sp.) or semi-arboreal (*D. oreas* and *L. septentrionalis*) and often forage on the ground for invertebrates (*Atractus* sp.), or prey on frogs (*L. septentrionalis*) or slugs and snails (*D. oreas*). In the latter three species, the color pattern varies in various shades of dark brown and yellow with darker irregular or angular blotches, however, a vertebral stripe is not present.

Abundance

Porthidium arcosae can be remarkably abundant in dry and xeric forests in the Province of Manabí. Barragán et al. (2001) reported 147 snake individuals collected between March and June 2000 in the Jipijapa district (Province of Manabí), among which *P. arcosae* was the second most abundant snake in the collection, accounting for 33 individuals (22.4%) of the total; May and April were the richest months with 18 and 13 captured, respectively. Out of the 33 individuals, 14 were males (42.42 %), 8 females (24.24 %) and 11 juveniles (33.33 %).

Longevity

Information on the longevity of *P. arcosae* was not available. The maximum longevity of a healthy specimen (FHGO live coll. 2160) refers to an individual held at the Vivarium-Quito for almost twelve years. It is still alive. Other specimens maintained under the same conditions at the Vivarium-Quito survived more than eight years (FHGO 3777, 7303; FHGO live coll. 2286, 2462, 2463).

Snakebite and envenomation

One envenomation case due to snakebite by *P. arcosae* was recorded. The bite happened in the venom snake laboratory in the FHGO, and hospitalization occurred in the VozAndes Hospital, Quito. A 29-years-old male person was bitten on August 1, 2002, at 14:30 on the second finger of his right hand. Local swelling at the site of the bite appeared within 20 minutes. The patient was hospitalized within 30 minutes of the bite and found to be in normal condition at first view (temperature 36.6 ºC, conscious and oriented) but with evidence of inflammation, ecchymosis (hematoma) and peripheral venous pulsations.

Laboratory tests identified slight changes in the cellular composition of the blood (10 and 20 minutes leukocytes 8.5%, segmented neutrophil granulocytes 54%, lymphocytes 35%, monocytes 7%, eosinophils 4%, and platelets 204000/µl). Circumferences of the affected right upper extremity measured about 16 hours after the bite, were: hand 24.0 cm, forearm 25.0 cm, upper arm 25.0 cm as compared to the left upper extremity (not affected) which measured: hand 22.0 cm, forearm 23.5 cm, and upper arm 25.0 cm. The following two days (August 2 and 3), intensive pain developed at the site of the *P. arcosae* bite on the hand, extending from the arm to the back side of the shoulder. The treatment received by the patient at the hospital included analgesics, antibiotics and antitetanus prophylaxis whereas the administration of antiserum was not found to be necessary. The patient was discharged after four days.

Conservation status

Green & Campbell (1992), mentioned several aspects that predispose a population or species of pitvipers to be threatened with extinction, attributing particular importance to the crucial features of being: (1) inhabitant of islands or confined to small areas, (2) present in specialized habitats, (3) subject to high mortality rate, (4) present at low and or variable population densities, (5) present at low intrinsic rates of population growth, and (6) large body size. *Porthidium arcosae* was not included in this publication; nevertheless, this species meets at least several of the above mentioned specifications.

Porthidium arcosae was categorized as Endangered (EN) (Valencia 2005) under IUCN categories, because of its limited geographic distribution, its presence in dry forest only (point 1 and 2 arguments of threat proposed for populations of pitvipers by Green & Campbell 1992), the small number of records in nature and national and international museums, and the rapid destruction and decline of dry forest habitats. Currently, these arguments remain still valid since the dry forests are increasingly reduced in the Manabí province and the western region of Ecuador, especially in favor of agricultural and livestock activities (Cisneros-Heredia 2006b; Valencia et al. 2008a).

The known population of *P. arcosae* is currently under continuous threat because of habitat loss. The MNP is a unique and protected national park in this region, which may ensure the survival of this snake and other species of the flora and fauna in central-western Ecuador. Machalilla National Park, part of the Tumbesian region formed by endemic and fragile flora and fauna ecosystems (Dodson & Gentry 1991; Parker & Carr 1992; Paladines 2003; Aguirre-Mendoza & Kvist 2005) consists of 550 km^2 of natural forest; nonetheless, only ca. 60 km^2 overlap with the *P. arcosae* distribution range.

DISCUSSION

Geographic distribution and conservation aspects

Herpetofaunal studies in dry forests of Ecuador are scarce or limited to the MNP (see Parker & Carr 1992; Cisneros-Heredia et al. 2006). Some published data refer to taxonomic and phylogenetic analyses (e. g. Coloma 1995; Ron et al. 2004), and a few studies to the natural history (e. g. Cisneros-Heredia 2006a) of dry forest species. Limited information may include misidentification or produce confusion concerning the occurring species, even among biologists (see *Bothrops atrox* (Linnaeus, 1758) at the MNP, Parker & Carr 1992). This potential identification problem can negatively affect native people, farmers and ranchers who suffer from bites by poisonous snakes which may easily be confused with *Bothrops asper* (Barragán et al. 2001).

The pitviper snakes in the western region of Ecuador are represented by *Bothriechis schlegelii*, *Bothriopsis punctatus*, *Bothrocophias campbelli* (Freire-Lascano, 1991), *Bothrops asper*, *Lachesis acrochorda* (García, 1896), *Porthidium nasutum* and *P. arcosae* (Coloma et al. 2000; Campbell & Lamar 2004), and an undescribed dry forest species allied to *Bothrops asper* (E. Smith, pers. comm.), with only few species reported in dry forest: *Bothrops asper*, *B. punctatus*, and *Porthidium arcosae.*

Currently, *Porthidium arcosae* is known from the south-central west of the province of Manabí, but herein we propose to extend the potential range of this snake to the coastal region of Santa Elena. The ecological niche model allowed us to identify the potential distribution range of this snake and three conspicuous dispersion barriers. (1) A physical barrier: *Porthidium arcosae* inhabits dry forest in the coastal areas of the provinces of Manabí and most likely Santa Elena. This region is clearly isolated from the northern coastal regions by the Caráquez Bay; (2) a habitat barrier: the vegetation along the central coast of the Caráquez Bay

is of the Manglar vegetative composition type (see Sierra 1999). This wet vegetative system strictly divides the dry northern forested areas from the dry southern areas, only the latter being inhabited by *P. arcosae*; (3) the presence of interacting/competing species: Cisneros-Heredia & Yánez-Muñoz (2005) reported the occurrence of *Porthidium nasutum* 11 km NW of the Caráquez Bay. This is well in accordance with the northern limits of the range of *P. arcosae* reported here.

The province of Manabí is ecologically divisible into two major biomes: the northern portion formed by the Chocoan region (wet and evergreen forest of the western Andes) and the central and southwestern portion, including the province of Santa Elena, which constitutes part of the Tumbesian region (dry and xeric forest).

Compared to all other pitvipers, *P. arcosae* has the most restricted distribution in Ecuador. However, its pattern of distribution is shared with range area patterns of about 15 other species of amphibians and reptiles, restricted to the Tumbesian region (Cisneros-Heredia 2006a).

The MNP covers and only protects about 1.5% of the *P. arcosae* distribution range. The southern limit of this range is overlapping with a small private reserve area, the Bosque Protector Loma Alta. According to Gibson & Becker (2000), this reserve extends from 200 m a.s.l. to 830 m a.s.l. but includes almost exclusively forest above 300 m a.s.l.

The Tumbesian Region was first recognized as an important bird area due to its high biological diversity, degree of endemism and threat status (Stattersfield et al. 1998), and later as an area of amphibian endemism since it encompasses the overlapping ranges of twelve amphibian species of highly restricted range (Cisneros-Heredia 2006b). The tendency of endemism in the area similarly applies to plants and mammals (Dodson & Gentry 1991; Parker & Carr 1992; Albuja 1999; Paladines 2003; Aguirre-Mendoza & Kvist 2005; Aguirre et al. 2006). The current authors are confident that future research will allow them to propose the Tumbesian region as an area of reptilian endemism and high conservation priority.

Natural history aspects

Porthidium arcosae is restricted to xeric, dry, and semi-deciduous forests like other species of the genus such as as *P. dunni* (Hartweg & Oliver, 1938), *P. hespere* (Campbell, 1976), *P. lansbergii* (Schlegel, 1841), *P. ophryomegas* (Bocourt, 1868), and *P. yucatanicum* (Smith, 1941) (McCoy & Censky 1992; Campbell & Lamar 2004; Bryson et al. 2008). *Porthidium arcosae* is terrestrial with nocturnal and crepuscular activity, but some individuals may be found actively moving at different hours of day, similar to *P. dunni* (Johnson 1974) and *P. lansbergii* (Campbell & Lamar 2004).

Feeding seems to be specialized on lizards (tropidurid and teiid species) and rodents, in contrast to *P. dunni, P. nasutum*, *P. ophryomegas* and *P. yucatanicum* that feed on a diversity of anurans, lizards, snakes (including conspecifics), birds and mammals. There is ontogenic variation of prey selection in *P. arcosae* in that the juveniles prefer small lizards whereas adults and subadults favor rodents. This condition is present also in other pitvipers such as *Agkistrodon bilineatus* Günther, 1863, *Atropoides mexicanus* (Duméril, Bibron & Duméril, 1854) (Campbell & Lamar 2004), *Cerrophidion godmani* Günther, 1863 (Campbell & Solórzano 1992), *Crotalus oreganus* Holbrook, 1840, (Mackessy et al. 2003), and some members of the genus *Bothrops* (Andrade & Abe 1999). The diet of juvenile pitvipers can include invertebrates (Boada et al. 2005; Campbell & Lamar 2004); however, such prey was not found in the stomachs of the specimens reviewed. Nevertheless, invertebrates are very likely to be an alimentary option in this species, especially to juveniles.

The reproductive behavior *P. arcosae* in captive conditions is similar to other species of pitvipers (Leloup 1975; Sazima 1992) and includes combat between males, courtship to female and copula. The Vivarium of Quito-Ecuador maintains a permanent program of management and reproduction of pitvipers. However, at present, the captive breeding program of this snake is not successful. *Porthidium arcosae* appears to be more long-lived compared to other *Porthidium* species such as *P. nasutum* and

P. ophryomegas (above 12 years versus 6.5 years) (see SLAVENS & SLAVENS 2000).

Considering the body length, specimens of the genus *Porthidium* usually attain 30-50 mm total length. However, *P. arcosae* as well as *P. ophryomegas*, *P. porrasi* LAMAR, 2003 and *P. lansbergii*, are relatively large species, which can exceed 700 mm in rare cases (see CAMPBELL & LAMAR 2004). In contrast to *Porthidium nasutum, P. ophryomegas* and *P. porrasi* (see CAMPBELL & LAMAR 2004), *P. arcosae* does not show significant sexual differences in total length. Nonetheless, herein a relevant sexual dimorphism in *P. arcosae* is reported: adult females develop considerably wider heads than adult males.

Knowledge on the reproductive biology of the Ecuadorian pitvipers with restricted geographic distribution in captive breeding programs is important for long-term conservation to preserve the option for eventual recovery of a species or population to secured habitat (VALENCIA et al. 2008a). There is no doubt that the program is a necessary part of the national actions, which include research on the nature and habitat preservation of threatened species and current climate change influences.

ACKNOWLEDGMENTS

We are grateful to María Elena BARRAGÁN for loaning the specimens and/or provision of working space at Laboratorio de Anfibios y Reptiles FHGO, Fundación Herpetológica Gustavo Orcés (Quito); to Pablo PICERNO, Alexis BARAHONA, and Miguel ALCOSER for the assistance in the field and laboratory at the Vivarium de Quito; to Santiago MAIGUA for providing remarkable information and collection data of the database at FHGO; to Pablo MENÉNDEZ-GUERRERO, Patricio YÁNEZ and Pablo MEJÍA for revising the script; to Félix ALMEIDA, César ALVARADO, and Fernando AYALA (PUCE - Pontificia Universidad Católica del Ecuador, Quito) for supplying additional specimen data from several localities of Caráquez Bay. Specimen collection permission was issued by Freddy TRUJILLO, Ministerio de Salud Pública del Ecuador. Thanks to Union Provincial de Organizaciones Campesinas de Manabi (UPOCAM) for allowing access to different communities in the province of Manabí and its surroundings. This research was complementarily supported by the Fundación Herpetológica Gustavo Orcés, Vivarium de Quito, and The British Council (London).

REFERENCES

AGUIRRE-MENDOZA, Z. & KVIST, L. P. (2005): Floristic composition and conservation status of the dry forest in Ecuador.- Lyonia, Honolulu; 8 (2): 41-67.

AGUIRRE, Z. & KVIST, L. P. & SÁNCHEZ, O. & BALSLEV, H. (2006): Bosques secos en Ecuador y su biodiversidad; pp. 162-187. In: MORALES, M. & OLLGAARD, B. & KVIST, L. P. & BORSCHSENIUS, F. & BALSLEV, H. (eds.): Botánica económica de los Andes Centrales. La Paz (Universidad Mayor de San Andrés).

ALBUJA, L. (1999): Murciélagos del Ecuador. 2nd edition, Quito (Cicetronic Cía. Ltda. Offset), 288 pp.

ALMENDÁRIZ, A. (1991): Lista de vertebrados del Ecuador. Anfibios y reptiles.- Politécnica, Quito; 16 (3): 86-165.

ANDRADE, D. V. & ABE, A. S. (1999): Relationships of venoms ontogeny and diet in *Bothrops*.- Herpetologica, Lawrence; 55: 200-204.

BARRAGÁN, M. E. & VALENCIA, J. H. & GARZÓN, K. & VARGAS, A. (2001): Proyecto de mantenimiento, manejo y cría en cautiverio de vipéridos Ecuatorianos (Fase II y III). Fase piloto en la provincia de Manabí (Technical Report). Fundación Herpetológica Gustavo Orcés, Ministerio de Salud Pública del Ecuador; Quito; pp. 158.

BOADA, C. D. & SALAZAR-V. & FREIRE-LASCANO, A. & KUCH, U. (2005): The diet of *Bothrops asper* (GARMAN, 1884) in the Pacific lowlands of Ecuador.- Herpetozoa, Wien; 18 (1/2): 77-83.

BRODIE, E. D. III & BRODIE, E. D. Jr. (1994): Venomous snake mimicry; pp. 617-633. In: CAMPBELL, J. A. & LAMAR, W. W. (eds.): The venomous reptiles of the western hemisphere. Vol I. Ithaca, New York (Cornell University Press).

BRYSON, R. W. Jr. & NIETO-MONTES DE OCA, A. & REYES VELASCO, J. (2008): Phylogenetic position of *Porthidium hespere* (Viperidae: Crotalinae) and phylogeography of arid adapted hognosed pitvipers based on mitochondrial DNA.- Copeia, Washington; 2008 (1): 172-178.

CADLE, J. E. (1985): The Neotropical colubrid snake fauna (Serpentes: Colubridae): Lineage components and biogeography.- Systematic Zoology, Baltimore; 34 (1): 1-20.

CAMPBELL, J. A. & LAMAR, W. W. (2004): The venomous reptiles of the western hemisphere. Ithaca, New York (Cornell University Press), pp. 870.

CAMPBELL, J. A. & SOLÓRZANO, A. (1992): The distribution, variation, and natural history of the Middle American montane pitviper *Porthidium godmani*; pp. 223-250. In: CAMPBELL, J. A. & BRODIE, E. D. Jr. (eds.): Biology of pitvipers. Tyler, Texas (Selva Press).

CHAPMAN, A. D. & WIECZOREK, J. (eds) (2006): Guide to best practices for georeferencing. [Online reference]. Copenhagen: Global Biodiversity Information Facility < http://www.gbif.org > (last accessed: June 2010).

Cisneros-Heredia, D. F. (2006a): Distribution and ecology of the western Ecuador frog *Leptodactylus labrosus* (Amphibia: Anura: Leptodactylidae).- Zoological Research, Toronto; 27 (3): 225-234.

Cisneros-Heredia, D. F. (2006b): Amphibians, Machalilla National Park, province of Manabí, western Ecuador.- Checklist, São Paulo; 2 (1): 45-54.

Cisneros-Heredia, D. & Borja, M. O. & Proaño, D. & Touzet, J. M. (2006): Natural history and distribution of the Ecuadorian toad-headed pitvipers of the genus *Bothrocophias* (Squamata: Serpentes: Viperidae:Crotalinae).- Herpetozoa, Wien; 19 (1/2): 17-26.

Cisneros-Heredia, D. F. & Yánez-Muñoz, M. (2005): Reptilia, Viperidae, Crotalinae, *Porthidium nasutum*: distribution extentions and remarks on its range and records.- Checklist, São Paulo; 1 (1): 16-17.

Coloma, L. A. (1995): Ecuadorian frogs of the genus *Colostethus* (Anura: Dendrobatidae).- Miscellaneous Publications of the Museum of Natural History, University of Kansas, Lawrence; 87: 1-72.

Coloma, L. A. & Quiguango-Ubillús, A. & Ron, S. (2000): Reptiles del Ecuador: lista de especies y distribución. Crocodylia, serpentes y testudines. Version 1.1. 25 Mayo 2000. [Online reference]. Museo de Zoología, Pontificia Universidad Católica del Ecuador, Quito, < http://www.puce.edu.ec/Zoologia/repecua.htm > (last accessed: June 2010).

Dodson, C. H. & Gentry, A. H. (1991): Biological extinction in western Ecuador.- Annals of the Missouri Botanical Garden, St. Louis, Mo; 78 (2):273-295.

Elith, J. & Graham, C. H. & Anderson, R. P. & Dudik, M. & Ferrier, S. & Guisan, A. & Hijmans, R. J. & Huettmann, F. & Leathwick, J. R. & Lehmann, A. & Li, J. & Lohmann, L. G. & Loiselle, B. A. & Manion, G. & Moritz, C. & Nakamura, M. & Nakazawa, Y. & Overton, J. M. & Peterson, A. T. & Phillips, S. J. & Richardson, K. S. & Scachetti-Pereira, R. & Schapire, R. E. & Soberón, J. & Williams, S. & Wisz, M. S. & Zimmermann, N. E. (2006): Novel methods improve prediction of species' distributions from occurrence data.- Ecography, Oxford; 29: 129-151.

Gibson, C. & Becker, C. D. (2000): Chapter 6. Lack of institutional demand: Why a strong local community in western Ecuador fails to protect its forest; pp. 135-161. In: Gibson, C. & McKean, M. & Ostrom, E. (eds.): People and forests: communities, institutions, and the governance of forests. Cambridge, MA (Massachusetts Institute of Technology Press).

Green, H. & Campbell, J. A. (1992): The future of pitvipers; pp. 421-428. In: Campbell, J. A. & Brodie, E. D. Jr. (eds.): Biology of pitvipers. Tyler, Texas (Selva Press).

Hijmans, R. J. & Cameron, S. & Parra, J. (2005): WOLRDCLIM 1.3 [Online reference]. Museum of Vertebrate Zoology University of California, Berkeley, < http://biogeo.berkeley.edu/wolrdclim/methods.htm > and < http://www.worldclim.org > (last accessed: June 2010).

Hirzel, A. H. & Hausser, J. & Perrin, N. (2007): Biomapper 4.0. [Software package] Laboratory for Conservation Biology, Department of Ecology and Evolution, University of Lausanne, Switzerland. < http://www2.unil.ch/biomapper > (last accessed: June, 2010).

IGM [Instituto Geográfico Militar] (2008): Mapa físico del Ecuador 1: 1.000.000. Vol. 2008. Instituto Geográfico Militar, Quito, Ecuador.

Johnson, J. D. (1974): New records of reptiles and amphibians from Chiapas, Mexico.- Transactions of the Kansas Academy of Science, Lawrence; 76 (3): 223-224.

Leloup, P. (1975): Observations sur la reproduction de *Bothrops moojeni* Hoge en captivité.- Acta Zoologica et Pathologica Antverpiensia, Antwerpen; 62: 173-201.

McCoy, C. J. & Censky, E. J. (1992): Biology of the Yucatan hognosed pitviper, *Porthidium yucatanicum;* pp. 217-222. In: Campbell, J. A. & Brodie, E. D. Jr. (eds.): Biology of pitvipers. Tyler, Texas (Selva Press).

Mackessy, S. P. & Kwave, W. & Aahton, K. G. (2003): Ontogenetic variation in venom composition and diet of *Crotalus oreganus concolor*. A case of venom paedomorphosis?- Copeia, Washington; 2003 (4): 769-782.

Paladines, R. (2003): Propuesta de conservación del Bosque Seco en el Sur del Ecuador.- Lyonia, Honolulu; 4 (2): 183-186.

Parker, T. A. III & Carr, J. L. (1992): Status of forest remnants in the Cordillera de la Costa and adjacent areas of southwestern Ecuador.- Conservation International, Washington; RAP [Rapid Assessment Program] Working Papers No. 2.

Pearson, R. & Raxworthy, C. & Nakamura, M. & Peterson, T. (2007): Predicting species distribution from small numbers of occurrence records: a test case using cryptic geckos in Madagascar.- Journal of Biogeography, Oxford; 34: 102-117.

Phillips, S. J. & Anderson, R. P. & Schapire, R. E. (2006): Maximum entropy modelling of species geographic distributions.- Ecological Modelling, Amsterdam; 190: 231-259.

Ron, S. & Cannatella, D. C. & Coloma, L. A. (2004): Two new species of *Physalaemus* (Anura: Leptodactylidae) from western Ecuador.- Herpetologica, Lawrence; 60 (2): 261-275.

Sazima, I. (1992): Natural history of the jararaca pitviper *Bothrops jararaca* in southeastern Brazil; pp. 199-216. In: Campbell, J. A. & Brodie, E. D. Jr. (eds.): Biology of pitvipers. Tyler, Texas (Selva Press).

Schätti, B. & Kramer, E. (1993): Ecuadorianische Grubenottern der Gattungen *Bothriechis*, *Bothrops* und *Porthidium* (Serpentes: Viperidae.- Revue Suisse de Zoologie, Genève; 100 (2): 1-45.

Sierra, R. (ed.) (1999): Propuesta preliminar de un sistema de classificación de vegetación para el Ecuador continental. Proyecto Instituto Ecuatoriano Forestal y de Areas Naturales y de vida silvestre / Global Environment Facility - Banco Internacional de Reconstrucción y Fomento (INEFAN/GEF-BIRF) y EcoCiencia, Quito, Ecuador, pp. 193.

Slavens, F. L. & Slavens, K. (2000): Reptiles and amphibians in captivity: breeding, longevity, and inventory. Seattle, Washington (Slaveware Publishing), pp. 400.

Stattersfield, A. J. & Crosby, M. J. & Long, A. J. & Wege, D. C. (1998). Endemic bird areas of the world. Priorities for biodiversity conservation. BirdLife Conservation Series No. 7. BirdLife International, Cambridge, UK.

VALENCIA, J. H. (2005): Serpiente sabanera (*Porthidium arcosae*); p. 31. In: CARILLO, E. & ALDÁS, S. & ALTAMIRANO, M. & AYALA, F. & CISNEROS, D. & ENDARA, A. & MÁRQUEZ, C. & MORALES, M. & NOGALES, F. & SALVADOR, P. & TORRES, M. L. & VALENCIA, J. H. & VILLAMARÍN, F. & YÁNEZ, M. & ZÁRATE, P. (eds.): Lista Roja de los reptiles del Ecuador. Quito, Ecuador (Novo Millenium).

VALENCIA, J. H. & ARABELÁEZ, E. & GARZÓN, K. & PICERNO, P. (2008a): Notes on *Corallus blombergi* (RENDAHL & VESTERGREN, 1941) from Ecuador.- Herpetozoa, Wien; 21 (1/2): 91-94.

VALENCIA, J. H. & GARZON, K. & BETANCOURT-YEPEZ, R. (2008b): Notes on the reproduction of the Ecuadorian Toad-Headed Pitviper *Bothrocophias campbelli* (FREIRE-LASCANO, 1991).- Herpetozoa, Wien; 21 (1/2): 95-96.

WIECZOREK, J. (2001): Georeferencing Calculator, (Rev. 28 Feb 2007) [Online reference]. University of California, Berkeley, < http://maniset.org.gc.html >

DATE OF SUBMISSION: June 25, 2010 Corresponding editor: Heinz Grillitsch

AUTHORS: Jorge H. VALENCIA, George VACA-GUERRERO, Fundación Herpetológica Gustavo Orcés, Av. Amazonas 3008 y Rumipamba, Casilla 17 03 448, Quito, Ecuador < jvalencia@fhgo.org.ec >; Katty GARZÓN, Vivarium de Quito, Parque La Carolina, Quito, Ecuador < kgarzon@fhgo.org.ec >