Herpetofauna of the Bilsa Biological Station, province of Esmeraldas, Ecuador

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ABSTRACT: The Bilsa Biological Station is located on the Mache-Chindul mountains and protects some of the last rainforest remnants in the province of Esmeraldas, northwestern Ecuador. Since 2004, we have been inventorying the amphibians and reptiles of Bilsa. We found 109 species of herpetofauna (37 amphibians and 72 reptiles), representing 8% and 18% of the known species from Ecuador, respectively. We report distribution extensions for Sachatamia albomaculata, Hyalinobatrachium valerioi, Pristimantis muricatus, and P. rosadoi, and report the presence of several putatively undescribed species. We propose the Mache-Chindul mountains as a Key Biodiversity Area within the West Ecuadorian Endemic Area.

INTRODUCTION

The Mache-Chindul mountains are on the West Ecuadorian biogeographic region, recently identified as an endemic area in western South America (Anderson and Jarrín 2002; Cisneros-Heredia 2006b). These mountains preserve an important portion of the last remnants of coastal tropical forest on northwestern Ecuador, a region characterized by high species diversity (Clark et al. 2006; Conservation International 2007). The Bilsa Biological Station (BBS) was established in 1994 to protect 3,300 hectares of threatened coastal forest and its high diversity of flora and fauna, with a unique composition of species renowned by its endemism and rarity (Cerón et al. 1999; Josse 2001; Clark et al. 2006; Clay et al. 1995; Cuesta-Camacho et al. 2007; Guayasamin 2008). Although physically isolated from the Andes, Bilsa possesses both plant and animal species usually restricted to higher elevations in the Andes.

Unfortunately, the West Ecuadorian region is greatly threatened by habitat loss and fragmentation caused by rural-urban development, agricultural activities, uncontrolled logging, and an inadequate management of natural resources (Sierra 1996; Cisneros-Heredia 2006b). Less than 4% of the original northwestern Ecuadorian forests remain (Cerón et al. 1999). The massive habitat loss and fragmentation of surrounding areas called for an urgent inventory of the herpetofauna of the Bilsa Biological Station, in order to understand its diversity and to propose conservation plans. Previous knowledge of the herpetofauna of the Mache-Chindul mountains was reviewed by Almendáriz and Carr (1992). The aim of this article is to present an extensive updated list of the amphibians and reptiles recorded until 2004 in the Bilsa Biological Station, with comments on new distributional records and putative undescribed species.

MATERIALS AND METHODS

Study Site

The Bilsa Biological Station (BBS; 00°21’33”N 79°42’02”W; 300-750 m; Figure 1) is a private reserve of 3,300 hectares owned and managed by Fundación Jatun Sacha and located in the province of Esmeraldas, northwestern Ecuador. BBS shows a complex mosaic of disturbed and undisturbed habitats within the Mache-Chindul mountains, preserving remnants of tropical humid (300-600 m) and pre-montane forest (600-750 m, called foothill evergreen forest by Cerón et al. 1999). The average rainfall is between 1500-2000 mm per year. The dry season runs from July to December and the wet season from January to June. Most surrounding areas have been largely deforested for small-scale agriculture, although several forest fragments remain. Thirteen places on eleven trails inside BBS were studied (Figure 1): (a) Scientific station, (b) Red trail, (c) Monkey trail, (d) Duchas stream, (e) Aguacatal–Dós Bocas stream, (f) Orange trail, (g) Brown trail, (h) Piscinas trail, (i) Rompefrente stream, (j) White trail, (k) Duchas stream–Red trail, (l) Green trail, (m) Scientific station–Dógola road, and (n) Yellow trail. These sites represent remnants of pre-montane primary forest (site b), streams with small waterfalls (sites d, e, h, i, j, n), 15-25 year old-secondary forest partially logged with some large primary-forest trees (sites j, l, m), reforested areas with fruit and hardwood species (site a), and remnants of primary forest (sites c, f, g, k). In general, we differentiate three major habitats at BBS: evergreen forest, gallery forests (next to streams and waterfalls), and disturbed areas.

Data Collection

We conducted extensive field work, studied most herpetological collections with BBS material at Ecuadorian museums, and review all relevant literature. We carried out exhaustive visual encounter surveys (VES) during four sampling periods: 10-15 December 2006 (30 hours/person), 26 February-03 March 2007 (30 hours/person), 13-25 April 2008 (53 hours/person),
and 09-17 May 2008 (36 hours/person); always at 09:00h-13:00h and 20:00h-23:00h. We prepared voucher specimens only for species that were caught for the first time or presented difficulties for field identification (Appendix 1). Photographic vouchers (but not specimens) were subsequently obtained from February 2004 to January 2009. Measurements were taken with a 0.5 mm precision dial caliper. Anuran calls were recorded with a Sony microcassette-corder M-670V and analyzed with Sound Ruler Acoustic Analysis®, following bioacoustics parameters suggested by Angulo (2006).

We recognize three categories of records: confirmed, unconfirmed, and unidentified species. Confirmed species are those with voucher specimens deposited at the División de Herpetología of the Museo Ecuatoriano de Ciencias Naturales (DHMECN, Quito, Ecuador). Unconfirmed species correspond to species captured and released, but supported by photographic vouchers. Unidentified species correspond to specimens (collected or photographed) still in need of specific verification pending additional collections.

We follow Frost (2008) for amphibian taxonomy and UETZ Reptile Database (1995-2008) for reptilian taxonomy. Information on the conservation status is based on UICN (2008). Each species of the checklist is assigned to one or more habitat types based on field records and knowledge of its life history. Regional distribution, dial activity, and local distribution data are included. The Jaccard Index (J) was used to analyze community similitude between Bilsa Biological Station (BBS), and three nearby areas where extensive field sampling has been conducted: Buffer zone of the Cotachi Cayapas Natural Reserve (ZACC; 00°51’51”N 78°44’02”W, 39-350 m, Morales et al. 2002), Galeras–San Francisco del Cabo (SFC; 00°39’00”N 80°03’29”W, 0-220 m; H. M. Ortega-Andrade unpublished data) and Reserva Biológica Canandé (RBC; 00°27’04”N 79°08’45”W, 700 m, M. H. Yánez-Muñoz unpublished data). Governmental research permit #002 was obtained from the Ministerio del Ambiente del Ecuador.

**RESULTS AND DISCUSSION**

Thirty-seven species of amphibians and 72 species of reptiles were recorded in total at the Bilsa Biological Station (Appendix 1–3). The families Colubridae (34 spp.) and Polychrotidae (11 spp.) were diverse in the reptiles assemblage, while the families Hylidae (8 spp.) and Strabomantidae (8 spp.) were the most diverse families for amphibians (Table 1). About 33% of Bilsa’s herpetofauna is rare, with only one specimen registered for each species. *Cochranella mache*, globally classified as Critically
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Endangered by Cisneros-Heredia et al. (2009), was recorded, together with four species classified as Vulnerable: Bolitoglossa sima, Hyloxalus awa, Pristimantis muricatus, and Pristimantis rosadoi (Figure 2; Appendix 1). Forty-four percent of species recorded has a wide Neotropical distribution, 27% are characteristic to the Chocoan region, and 18% are endemic to the West Ecuadorian region. Four species are distributed in Ecuador and Peru (Appendix 1). Similarity indexes reveal that the Bilsa Biological Station is most similar to the Galeras-San Francisco del Cabo coastal tropical forest (SI = 0.48, 58 shared species), linked to a second cluster formed by the Zona de Amortiguamiento de la Cotacachi-Cayapas (SI = 0.34, 50 species shared) and Reserva Biológica Canandé (SI = 0.38, 45 species shared; Figures 1B and 3).

**Extension ranges**

*Pristimantis muricatus* This Ecuadorian-endemic species was previously known from six localities in humid lowlands and pre-montane slopes of the provinces of Pichincha and Esmeraldas, Ecuador, at elevations between 60 and 1380 m (Lynch and Duellman 1997; Morales et al. 2002; Figure 4). We collected a female specimen (DHMECN 3652; 36.52 mm in SVL) at the White trail on 13 December of 2006 (Figure 1A). This specimen was about 1 m above the ground on streamside vegetation at night.
Additional individuals were recorded (but not collected) on 15 October 2004, 16 November and 10 December 2006. A single female taking care of her eggs was recorded on a leaf 1.5 m above ground on the Orange trail. These records extend its distribution by ca. 109 km from the closest northern locality (near Tsepi, province of Esmeraldas; Morales et al. 2002), and ca. 109 km from the closest southern locality (near Centro Científico Río Palenque, province of Los Ríos; Lynch and Duellman 1997). Coloma et al. (2008) presented a map for *P. muricatus* comprising an estimated area of occurrence of approximately 7,849 km². Based on the new records from the Mache–Chindul mountains, the estimated area of occurrence of *P. muricatus* is ca. 8,705 km² (Figure 5).

**Pristimantis rosadoi** is a species distributed at Isla Gorgona, Colombia, and northwestern Ecuador; up to 800 m (Lynch and Duellman 1997; Cisneros-Heredia et al. 2004). New material (Figure 4) from the province of Esmeraldas was collected at the following localities: (a) Bilsa Biological Station, on 11 December 2006, an immature female (DHMECN 3638, 21.5 mm SVL); (b) Reserva Monte Saino (0°4′21″26″N 79°08′45″W, 160-220 m), three gravid females (DHMECN 2758, 27.2 mm SVL; DHMECN 2760, 26.3 mm SVL; DHMECN 2781, 24.25 mm SVL) and three males (DHMECN 2757, 19.3 mm SVL; DHMECN 2759, 18.3 mm; DHMECN 2782, 17.0 mm SVL), on 13 February, 19 March, 21-22 April and 16 September 2004; (c) Reserva Biológica Canandé, (00°27′04″N 79°08′45″W, 700 m), two gravid females (DHMECN 2823, 22.0 mm SVL; DHMECN 2824, 25.65 mm SVL) and one male (DHMECN 2820, 17.45 mm SVL), on August 2004. An amplectant pair (DHMECN 2781-82) was captured on a leaf at night on 22 April 2004; the female specimen contained 52 mature eggs in the oviduct. The record at Reserva Monte Saino extends the species’ distribution ca. 108 km from the closest northern locality (near Tangareal, province of Esmeraldas; Morales et al. 2002), and ca. 122 km from the closest southern locality (near to Río Caoní, province of Pichincha; Lynch and Duellman 1997). Based on the records presented herein, the estimated area of occurrence of *P. rosadoi* is ca. 11,884 km² (Figure 5).

**Hyalinobatrachium valerioi** (Figure 4) is widely distributed from central Costa Rica, through Panama and the Pacific lowlands of western Colombia and western Ecuador (Duellman and Burrowes 1989; Cisneros-Heredia and McDiarmid 2007; Solís et al. 2008). We report the first record of *Hyalinobatrachium valerioi* from the province of Esmeraldas. This record is the westernmost locality of the species, ca. 186 km from the nearest locality (Maldonado, province of Carchi, Duellman & Burrowes 1989) and ca. 116 km from the most southeastern locality (Centro Científico Río Palenque, province of Pichincha: Figure 7). A male (Figure 4) was recorded, but not collected, on the underside of a *Heliconia* leaf, 2.5 m above ground, near the Duchos stream at night on 27 January 2008. A metamorphic individual was observed in the Aguatatal-Dos Bocas Stream at night on 10 May 2008 (Figure 4D); eight masses with 20-72 eggs (x = 41.3, N = 8) were recorded between 13 April and 16 May 2008 on the underside of leaves 0.3-6 m above a stream. Eggs clutches were guarded by calling males on the underside of leaves. We analyzed 13 calls from a single male (SVL = 22.57 mm; not collected) recorded on 13 April 2008 at the Duchos stream, ca. 3 m above water. Calls consist of a single note with an average dominant frequency of 6393.7 kHz ±217.2 Hz, fundamental frequency 3196.85 KHz ±108.60 Hz, and average call duration 0.0517s ±0.02s (Figure 6). Cisneros-Heredia and McDiarmid (2007) suggested that several species maybe under the name *H. valerioi*.

**Sachatamia albomaculata** (Figure 4) was reported for the first time for Ecuador by Guayasamin et al. (2006), thus extending its distribution range from humid lowlands and premontane slopes from north-central Honduras to northwestern Ecuador. In April 2007 two amplectant specimens were recorded, but not collected, by G. Jongsma and R. Hedley, near the Piscinas Trail (Figure 1). The Bilsa Biological Station is the southernmost locality in the distributional range of *S. albomaculata*, extending the known geographic range by 66.8 km from its closest northern locality (Reserva Biológica Canandé; Guayasamín et al. 2006; Figure 7). At BBS, *S. albomaculata* and *Hyalinobatrachium valerioi* were found in sympathy with Cochranella mache, Teratohyla pulverata and Espadarana prosoblepon.

**Comments on unconfirmed species**

**Econiomiohyla sp.** (cf. *phantasmagoria*): A juvenile (uncollected; Figure 10) was found on a leaf close to the ground at a stream next to the Duchos stream at night on 30 January 2008. This frog had a dorsum mottled brown, black, and dark green; areolated belly, chest, and throat white with black blotches; ventral surfaces of limbs bright yellow with black blotches; large digital discs and extensive webbing; and scalloped dermal flaps along the outer limb margins. *Econiomiohyla phantasmagoria* is known to occur at two localities separated by 1,000 km: Río Cauca, near the border of the departments of Antioquia and Bolivar in north-western Colombia; and, extreme north-western province of Esmeraldas, Ecuador; at 500 m (Frost 2008; Jungfer and Renjifo 2008). We revised photographs of the specimen reported as *E. phantasmagoria* by Jungfer and Renjifo (2008) deposited at the National History Museum of Vienna (NHMW 32168). It coincides with the characteristics described for the species and is morphologically similar to the juvenile from Bilsa, although differ in the ventral color pattern and presence of the supratympanic fold.

**Atractus sp.** (cf. *microrynchus*): A specimen of a unicolor *Atractus* with a light collar (Figure 8) was found (uncollected) on 24 October 2007. It has the following characteristics: (1) 17 scale rows; (2) smooth dorsal scales; (3) dorsal scales rows same number through body; (4) loreal longer than the eye diameter; (5) 7 infralabials; (6) 35 divided subcaudals; (7) uniform black dorsum; and (8) complete cream collar. Additional characters of its epideresis are: One rostral, two internasals, two prefrontals, one frontal, one supraccular, two parietals, two nasals, one large loreal, no preocclusals, two postoculars, 1+2 temporalis, 7 supralabials, 7 infralabials, 17 scale rows, 35 divided subcaudals, 148 mm total length. The only other uniform dark snake with collar in northwestern Ecuador that could be confused with this species is *Ninia atrata*, which has 19 rows at midbody with all dorsal scales keeled.
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Figure 4. *Pristimantis muricatus* (A), *Pristimantis rosadoi* (B), *Hyalinobatrachium valerioi* (C-D) and *Sachatamia albomaculata* (E) from Bilsa Biological Station, northwestern Ecuador. Photos: J. Bermingham, C. Aulestia and C. Paucar.
Figure 5. Distribution map of *Pristimantis muricatus* (triangles) and *P. rosadoi* (circles) for Ecuador. Red star: Bilsa Biological Station; black circles: collections of DHMECN in Reserva Monte Saino and Reserva Biológica Canandé; grey circles and triangles: literature records (Lynch and Duellman 1997, Morales in litt.). A green line indicates elevations above 500 m, a darker brown line indicates elevations above 2000 m, and a black thin line indicates elevations above 3800 m.

Figure 6. A continuous sequence of four calls emitted by *Hyalinobatrachium valerioi* (A), waveform of a single call (B) and its spectrogram (C). Recorded on 13 April 2008 at Duchas stream, single male (SVL = 22.57 mm; not collected).
Figure 7. Distribution map of *Hyalinobatrachium valerioi* (triangles) and *Sachatamia albomaculata* (circles) for Ecuador. Red star: Bilsa Biological Station; blue circles and triangles: literature records (Duellman and Burrowes 1989; Guayasamin et al. 2006; Cisneros-Heredia and McDiarmid 2007; Solís et al. 2008). A green line indicates elevations above 500 m, a darker brown line indicates elevations above 2000 m, and a black thin line indicates elevations above 3800 m.

Figure 8. *Atractus* sp. (cf. *microrhynchus*), not collected, from Bilsa Biological Station, northwestern Ecuador. Photos: H. M. Ortega-Andrade.

Figure 9. *Atractus* sp. (cf. *melas*) (A) and *Sibon* sp. (B) from Bilsa Biological Station, northwestern Ecuador. Photos: J. Bermingham.
Atractus sp. (cf. melas): This snake (Figure 9) is characterized by: (1) medium-sized body (about 400-500 mm); (2) cylindrical body; (3) head not differentiated from the body; (4) small eyes; (5) short tail; (6) smooth dorsal scales, lacking apical pits; (7) dorsally there is a series of alternate, white regular bands separated by dark black interspaces; head black with a bright red collar on the neck extending through the labial scales; (8) ventral surfaces red. The only similar snake in northwestern Ecuador is the elapid Micrurus mipartitus, which has complete black and cream rings through the body and a bright red tail.

Sibon sp. (Figure 9) is characterized by: (1) medium-sized body (450-550 mm); (2) 15 row scales, (3) body laterally compressed; (4) neck pronounced; (5) seven supralabials, commonly 5–7 in contact with the ocular orbit; (6) dark red eyes, vertical elliptic pupils; (7) dorsal scales smooth, without apical pits; (8) dorsally there is a series of 42 alternate, reddish, regular bands separated by green and white interspaces bordered with black. Sibon sp. may be an undescribed species of the Sibon annulatus species group (J. Savage pers. comm.). Members of this group are Sibon annulatus, S. argus, S. dimidiatus, S. longifrenis, S. lamari, S. manzanaresi and S. miskitus, all from Central America (Savage and McDiarmid 1992; Uetz 1995-2008). The dorsal color pattern, vertebral scales slightly enlarged than other dorsal scales, and 7 supralabial scales immediately differentiate Sibon from Sibon nebulata, Dipsas andiana and D. gracilis at Bilsa.

Four specimens (DHMECN 3632, 3649, 3785, 3786) are assigned to Colostethus (Grant et al. 2006) and seem to correspond to a putatively undescribed species characterized by: (1) finger III not swollen in adult males; (2) dorsolateral stripe absent; (3) cream oblique lateral stripe present, constricted, discontinued, fading to gray in inguinal region, but continuing; (4) ventral surface of body immaculate cream to white in females; throat and chest marbling or blotched as brown-dark grey in adult males, belly uniform cream; (5) dorsum reddish brown in life; (6) bright yellow axillary, inguinal and shank flash marks. Colostethus panamensis is the only species in the Choco Region that has yellow bright marks in the armpit, groin and shanks (Grant 2004). Colostethus sp. (Figure 10) differs from C. panamensis in being the oblique pale stripe extending from the groin to eye (extending only midway to eye in C. panamensis), by has pale brown with scattered diffuse cream flecks in the flanks, between the ventrolateral and oblique lateral stripes, whereas that region is solid dark brown in C. panamensis and adult
males with blotched chest (Grant 2004). Relative tympanic size is also diagnostic between both species: conspicuous and large in Colosthetus sp., while inconspicuous and small in C. panamensis. Other sympatric dendrobatids at Bilsa are Oophaga sylvatica, Epipedobates boulengeri and Hyloxalus awa.

Pristimantis sp. (Figure 10) is apparently the same undescribed species cited as Eleutherodactylus sp. by Cisneros-Heredia (2006a) from Parque Nacional Machalilla, in the Province of Manabi. Two specimens were captured by C. Aulestia on the night of 16 November 2006 and by C. Paucar on 25 April 2008, both near to the Duchas stream. These specimens had granular ventral skin and white marks on the dorsal surfaces of the body and legs.

A specimen (DHMECN-HMOA 1360) assigned to the genus Euspundylus was found dead on the road that leads from the scientific station to La Yecita by L. M. Krogstad on 9 November 2007 (Figure 11). The specimen is characterized by: (1) Head slightly longer than wide; (2) no granular dorsal scales; (3) nasal scales separated from each other by the rostral and frontalnasal scales; (4) presence of ear opening with reeded tympanum; (5) moveable eyelids; (6) limbs each with five well developed, clawed digits; (7) interparietal scale larger than the length of parietal scales, and together their posterior border not forming an aligned transverse straight suture across the back of the head; (8) no granular scales on the neck; (9) lateral scales reduced in size; (10) dorsal brown with black marks through the body; (11) ventral surfaces with black scales bordered with bright yellow. Only Euspundylus guentheri and Euspundylus maculatus are currently reported for Ecuador, but both occur on the eastern flanks and tropical lowland forest of Ecuador (Coloma et al. 2000-2009).

We have photographs of an unidentified caecilian, a lizard of the genus Psychoglossus, and two Colubrid snakes that could not be assigned to any known species from the western Ecuador (Figure 11).

The documented herpetofauna of Bilsa Biological Station represents the 8 % and 18 % of the total number of amphibians and reptiles recorded for Ecuador, respectively (Coloma et al. 2000-2009; Torres-Carvajal 2000-2009; Coloma 2005-2009). Bilsa Biological Station is the second richest area in the Pacific slopes of Ecuador, surpassed only by the Centro Científico Río Palenque, west-central Ecuador (Miyata in litt.), where 145 species were reported. Since most of Palenque’s forest have been lost due to fragmentation and uncontrolled logging (Wilson 1991), the Mache-Chindul Mountains are the last remnants of tropical-subtropical forests in the northwestern Ecuador, identified as a Priority Area of Conservation (Cuesta-Camacho et al. 2007).

Amphibian and reptile communities are known to be sensitive to environmental changes and are easily affected by fragmentation, logging and changes in microclimatic variables through a disturbed gradient in the habitat structure (Pearman 1997; Alcala et al. 2004; Urbina-Cardona et al. 2006). After 149 hours/person sampling with VES, a total of 668 individuals of 58 species were captured (29 amphibian and 29 reptiles). In forested areas we captured 196 specimens from 13 amphibians and 24 reptiles. The most frequent amphibian species were Pristimantis achatinus (30 %), Oophaga sylvatica (28 %), Pristimantis latidiscus (20 %) and Rhinella margaritifera (7 %). For reptiles, the most frequent species were Alopoglossus festae (21 %), Lepidobatrachus rathueni (12 %), Anolis gracilipes, Oxybelis brevirostris and Enyalioides heterolepis, with 8 specimens each one. In forested areas with streams/waterfalls we captured 463 specimens of 19 amphibians and 8 reptiles. In contrast with the forested areas, the most frequent amphibians were Esparadana prosoblepon (29 %), Hypsiboas picturatus (28 %), Cochranella mache (11 %) and Pristimantis achatinus (10 %). We captured only 9 individuals corresponding to the lizards Anolis lynchii (2 %), Basiliscus galeritus, Enyalioides heterolepis, Echinosaursa horrida and the snakes Dipas gracilis, Imanotodes cenchua, Leptodeira septentrionalis ornata and Trachyboa boulengeri. In disturbed areas near to streams, swamps or roads on station, we captured 21 individuals of 10 amphibians and 9 reptiles. We found five anurans (Hypsiboas boans, Hypsiboas pellucens, Hypsiboas rosenbergi, Leptodactylus labrosus, Scinax quinquefasciatus) solely associated to this type of habitat. The lizard Anadia rhombifera was observed moving on the roof and walls of the station building, near to the kitchen. Iguana iguana was observed on the canopy of a remnant tree, near to the station entrance. We observed a reduction in the amphibian richness (41 %) through the habitat gradient. Hylid frogs were closely associated to swamps and remnants forest in disturbed areas, while most Glassfrogs, Strabomantid and Dendrobatid frogs were associated to forested areas. A similar pattern of species replacement was found at Isla Gorgona, Colombia (Urbina-Cardona and Londoño 2003).

The lowland forests of the Pacific slopes of Ecuador are home to many unique species of plants and animals (Dodson and Gentry 1978; Albija 1999; Cisneros-Heredia 2006b; Albija and Arcos 2007). Separated by millions of years from their relatives in the Amazon basin by the Andes, they evolved here in geographic isolation (Duellman 1979; 1999; Ron 2000). Lynch and Duellman (1997) mentioned a gradual latitudinal displacement of related species of Strabomantid frogs through the Choco, with two major breaks: the first located in northern Departamento del Valle, Colombia with a considerable endemism of species, and a second major break between La Munchique in Departamento del Cauca, Colombia, and La Planada in southern Departamento de Nariño, Colombia. According to their analysis, the authors observed a disruption in the replacement of sister species like Strabomantis anatipes and S. zygodactylus – the former to the north of the Río San Juan Valley and the latter to the south of the river. Composition of Pristimantis species at Bilsa (Appendix 1) match with the southernmost Chocoan community reported by Lynch and Duellman (1997), with only Craugastor longirostris and Pristimantis achatinus distributed from Panama to western Ecuador. Low values in community similarity index between Bilsa and three other localities in northwestern Ecuador (Figures 1 and 3), reveals a replacement of species through the study area, therefore a high beta diversity in the province of Esmeraldas marked by an important component of endemic species (Appendix 1). Some differences may be explained by different sampling efforts between the studies compared here. However, 18 % of the species at
Bilsa are unique to lowland and foothill evergreen forest of Ecuador (0-800 m), supporting that the West Ecuadorian Area, is a biogeographic region different from the Choco and Tumbesian regions (Cisneros-Heredia 2006b). The lowlands of the Department of Nariño in southwestern Colombia have not been collected intensively (Lynch and Duellman 1997), and it is possible that some species like *P. colomai*, *P. muricatus*, *Hyloxalus awa* or the lizards *Alopoglossus festae* and *Anolis peracciae* could extend the limit of the West Ecuadorian Endemic Area to southwestern Colombia.

Current knowledge of Ecuadorian herpetofauna still does not allow us to develop an adequate conservation assessment for most populations of amphibians and reptiles in the country, and Bilsa is not the exception. The presence of new distributional records and new species are clear evidences that the Pacific slopes of Ecuador are understudied. Much of the herpetofauna diversity in the Pacific slopes of Ecuador is threatened by habitat loss, high deforestation rates due to unsustainable development, fragmentation, extension of the agricultural frontier, global climate change, among others. Future studies at Bilsa must include population and community ecology assessment and studies of the effects of habitat loss and fragmentation. New herpetological collections are urgently necessary to obtain specimens of species herein reported as putatively undescribed. We encourage prioritizing conservation actions on endemic and key areas, as well as increasing herpetofaunal research. We propose that the Mache–Chindul Mountains should be recognized as a Key Biodiversity Area (Gascon et al. 2007), globally important site that is large enough and sufficiently interconnected to ensure the persistence of remaining populations of endangered and endemic species in northwestern Ecuador.

**Figure 11.** Caecilid sp. (A), *Ptychoglossus* sp. (B), *Euspondylus* sp. (C), *Chironius* sp. (D), and Colubrid sp. (E) from Bilsa Biological Station, northwestern Ecuador. Photos: J. Bermingham, K. Maier and H. M. Ortega-Andrade.
APPENDIX 1. Species list of amphibians and reptiles from the Bilsa Biological Station, province of Esmeraldas, Republic of Ecuador. Trail: (a) Scientific

**AMPHIBIA**

| CLASS/Order/Family/Species | Trail | Habitat | Diel Activity | Distribution Pattern | Conservation Status |
|----------------------------|-------|---------|---------------|----------------------|---------------------|
| **Anura**                  |       |         |               |                      |                     |
| Bufoidae                   |       |         |               |                      |                     |
| 1  |  |  |  |  |  |
| 2  |  |  |  |  |  |
| 3  |  |  |  |  |  |
| Centrolenidae              |       |         |               |                      |                     |
| 4  |  |  |  |  |  |
| 5  |  |  |  |  |  |
| 6  |  |  |  |  |  |
| 7  |  |  |  |  |  |
| 8  |  |  |  |  |  |
| 9  |  |  |  |  |  |
| Craugastoridae             |       |         |               |                      |                     |
| 10 |  |  |  |  |  |
| Dendrobatidae              |       |         |               |                      |                     |
| 11 |  |  |  |  |  |
| 12 |  |  |  |  |  |
| 13 |  |  |  |  |  |
| 14 |  |  |  |  |  |
| Hylidae                    |       |         |               |                      |                     |
| 15 |  |  |  |  |  |
| 16 |  |  |  |  |  |
| 17 |  |  |  |  |  |
| 18 |  |  |  |  |  |
| 19 |  |  |  |  |  |
| 20 |  |  |  |  |  |
| 21 |  |  |  |  |  |
| 22 |  |  |  |  |  |
| Leptodactylidae            |       |         |               |                      |                     |
| 23 |  |  |  |  |  |
| 24 |  |  |  |  |  |
Appendix 1. Species list of amphibians and reptiles from the Bilsa Biological Station, province of Esmeraldas, Republic of Ecuador. Trail: (a) Scientific Station, (b) Red Trail, (c) Monkey trail, (d) Duschas stream, (e) Aguacatal–Dos Bocas stream, (f) Orange trail, (g) Brown trail, (h) Piscinas Trail, (i) Rompefrente stream, (j) White trail, (k) Duschas stream–Red trail, (l) Green trail, and (m) Scientific Station–Dogola road. Habitat: D = disturbed areas; F = forest, R = river, S = stream, Sw = swamp. Diel activity: D = diurnal, N = nocturnal, ? = unknown. Distribution pattern: CO = Colombia, EC = Ecuador, PA = Panama, PE = Peru, ND = no data, W = wide distribution. Conservation Status according to UICN (2008): DD = Data Deficient, EN = Endangered, LC = Least Concern, NE = Not Evaluated, NT = Near Threatened, VU = Vulnerable.

| CLASS/ Order/ Family/ Species | Trail | Habitat | Diel Activity | Distribution Pattern | Conservation Status |
|-------------------------------|-------|---------|---------------|-----------------------|---------------------|
| Strabomantidae                |       |         |               |                       |                     |
| 25 Pristimantis achatinus     | b,c,d,e,f,g,h,i,j,l | FS,Sw,D | N | PA-CO-EC | LC |
| 26 Pristimantis latidocus     | c,d,e,f,g,h,i,j,l | FS | N | CO-EC | LC |
| 27 Pristimantis muricatus     | j | FS,D | N | EC | VU |
| 28 Pristimantis parvillus     | g,l | F | N | CO-EC | LC |
| 29 Pristimantis rosadoi       | e,h | F | N | CO-EC | VU |
| 30 Pristimantis sp.           | d | S | N | EC | NE |
| 31 Pristimantis subsigillatus | b | F,D | N | CO-EC | LC |
| 32 Pristimantis walkeri       | a | F | N | EC | LC |
| Caudata                       |       |         |               |                       |                     |
| Plethodontidae                |       |         |               |                       |                     |
| 33 Bolitoglossa biseriata     | j,l | FS | N | W | LC |
| 34 Bolitoglossa sima          | d,j,l | FS | N | EC | VU |
| 35 Oedipina complex           | l | FS,F,D | ? | ND | NE |
| Gymnophiona                   |       |         |               |                       |                     |
| Caeciliidae                   |       |         |               |                       |                     |
| 36 Caecilia nigricans         | a | F,D | ? | W | LC |
| 37 Caecilid sp. 1             | l | F,D | ? | ND | NE |
| Squamata-Amphisbaenia         |       |         |               |                       |                     |
| Amphibiaeida                  |       |         |               |                       |                     |
| 1 Rhinoclemmys annulata       | c | RS,Sw,F | N/D | W | |
| Squamata-Sauria               |       |         |               |                       |                     |
| Anguidae                      |       |         |               |                       |                     |
| 3 Diploglossus monotropis     | m | F,D | D | W | |
| Corytophanidae                |       |         |               |                       |                     |
| 4 Basitarsus galeritus        | h | RS | D | W | |
| Gymnophthalmidae              |       |         |               |                       |                     |
| 5 Alopoglossus festae         | a,b,c,g,j | F,D | D | EC | |
| 6 Anadia rhombifera           | a | F,D | D | CO-EC | |
| 7 Echinosaura horrida         | d,k | S | D | CO-EC | |
| 8 Euspondylus sp.             | m | F | D | EC | |
| 9 Psychoglossus gorgonae      | a | F | D | CO-EC | |
| 10 Psychoglossus sp.          | a | F | D | ND | |
| 11 Teuchocercus keyi          | n | SF | D | EC | |
| Hoplocercidae                 |       |         |               |                       |                     |
| 12 Enyalioides heteroleptis   | c,d,e,f,g,j | FS | D | CO-EC | |
| 13 Enyalioides osaughnessyi   | g | ES | D | W | |
| Iguanidae                     |       |         |               |                       |                     |
| 14 Iguana iguana iguana       | a | F | D | W | |
| Phyllodactylidae              |       |         |               |                       |                     |
| 15 Thecadactylus rapicauda    | g | F,D | D | W | |
| Polychrotidae                 |       |         |               |                       |                     |
| 16 Anolis biporatus           | l | FS,D | D | CO-EC | |
| 20 Anolis chorcorum           | g | F,D | D | PA-CO-EC | |
| 21 Anolis fraseri             | a | F,D | D | CO-EC | |
| 22 Anolis gracilipes          | c,e,f,g,j | FS,D | D | EC | |
| 23 Anolis granuliceps         | a | FS,D | D | CO-EC | |
| 24 Anolis leachi              | e,h,i | S | D | CO-EC | |
| 25 Anolis lora                | c | F,D | D | W | |
| 26 Anolis maculiventris       | a | F | D | CO-EC | |
| 27 Anolis peraccae            | a,j | F,D | D | EC | |
| 28 Anolis princeps            | c,e | F,D | D | CO-EC | |
| Sphaerodactylidae             |       |         |               |                       |                     |
| 16 Lepidoblemaphis buchwaldi  | a,b,c | SF | D | EC | |
| 17 Lepidoblemaphis grandis    | a,e | S | D | EC | |
| 18 Lepidoblemaphis ruthvenii  | a,c,j | S | D | CO-EC | |
| 29 Polychrus guttatus         | a | F | D | W | |
| Teiidae                       |       |         |               |                       |                     |
| 30 Ameiva septemlineata       | b,g | SR,D,F | D | EC | |
| Squamata-Serpentes            |       |         |               |                       |                     |
| Boidae                        |       |         |               |                       |                     |
| 31 Boa constrictor imperator  | a | F,D | N/D | W | |
APPENDIX 1. Species list of amphibians and reptiles from the Bilsa Biological Station, province of Esmeraldas, Republic of Ecuador. Trail: (a) Scientific Station, (b) Red Trail, (c) Monkey trail, (d) Dugas stream, (e) Aguaclal-Dos Bocas stream, (f) Orange trail, (g) Brown trail, (h) Piscinas Trail, (i) Rompefrente stream, (j) White trail, (k) Dugas stream–Red trail, (l) Green trail, and (m) Scientific Station–Dógola road. Habitat: D = disturbed areas; F = forest, R = river, S = stream, Sw = swamp, Fs = fosorial. Diel activity: D = diurnal, N = nocturnal, ? = unknown. Distribution pattern: CO = Colombia, EC = Ecuador, PA = Panama, PE = Peru, ND = no data, W = wide distribution. Conservation Status according to UICN (2008): DD = Data Deficient, EN = Endangered, LC = Least Concern, NE = Not Evaluated, NT = Near Threatened, VU = Vulnerable.

APPENDIX 2. Collected material from Bilsa Biological Station, province of Esmeraldas, northwestern Ecuador.

AMPHIBIA
Anura: Bufonidae: Rhinella haematiticus DHMECN 3631, Rhinella margaritae DHMECN 3627 Centromenidae: Espadarana prosoblepon DHMECN 3635; Dendrobatidae: Colostethus sp. DHMECN 3632, DHMECN 3649, DHMECN 3788, DHMECN 3786, Eupolobates boulengeri DHMECN 3793; Hypsiboas awa DHMECN 3628, DHMECN 3633; Oophaga sylvatica DHMECN 3629, DHMECN 3630; Hyliidae: Agalychnis spurrelli DHMECN 3792; Hyspisboas picturatus DHMECN 3622; Snelliscia phaeota DHMECN 3623; Leptodactylidae: Leptodactylus labrosus DHMECN 3789; Strabomantidae: Pseudobois picturatus DHMECN 3637, DHMECN 3639, DHMECN 3658, DHMECN 3662; Pristimantis maricatus DHMECN 3656, DHMECN 3663; Pristimantis rosadoi DHMECN 3638; Pristimantis subsigillatus DHMECN 3796. Caudata: Plethodontidae: Bolitoglossa biriatera DHMECN 3653, DHMECN 3655; Bolitoglossa sima DHMECN 3654, DHMECN 3791; Oedipina complex DHMECN 2607.

REPTILIA
Squamata: Anguidae: Diploglossus monotypus DHMECN 3664; Colubridae: Coniophanes fissidens DHMECN 3659; Dipas andiana DHMECN 3655; Dipas gracilis DHMECN 3622; Leptodactylus labrosus DHMECN 3789; Strabomantidae: Pseudobois picturatus DHMECN 3637, DHMECN 3639, DHMECN 3658, DHMECN 3662; Pristimantis maricatus DHMECN 3656, DHMECN 3663; Pristimantis rosadoi DHMECN 3638; Pristimantis subsigillatus DHMECN 3796. Caudata: Plethodontidae: Bolitoglossa biriatera DHMECN 3653, DHMECN 3655; Bolitoglossa sima DHMECN 3654, DHMECN 3791; Oedipina complex DHMECN 2607.
APPENDIX 3. Amphibians and Reptiles from Bilsa Biological Station, northwestern Ecuador. Photographers: J.S. Bermingham (JB), C.F. Aulestia-Obanda (CA), H. M. Ortega-Andrade (MO), E. Neuschulz (EN) and Christian Paucar (CP).

*Rhinella haematiticus* (CP) - *Bufonidae*

*Rhaebo haematiticus* (JB) - *Bufonidae*

*Rhinella margaritifera* (JB) - *Bufonidae*

*Rhinella margaritifera* (JB) - *Bufonidae*

*Rhinella marina* (juvenile) (JB) - *Bufonidae*
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Espadarana prosoblepon (JB) - CENTROLENIDAE
Sachatamia albomaculata (CP) - CENTROLENIDAE

Cochranella mache (JB) - CENTROLENIDAE
Teratohyla pulverata (JB) - CENTROLENIDAE

Hyalinobatrachium valerioi (JB) - CENTROLENIDAE
Hyalinobatrachium fleischmanni (JB) - CENTROLENIDAE
**APPENDIX 3.** Amphibians and Reptiles from Bilsa Biological Station, northwestern Ecuador. Photographers: J.S. Bermingham (JB), C.F. Aulestia-Obanda (CA), H. M. Ortega-Andrade (MO), E. Neuschulz (EN) and Christian Paucar (CP). *(CONTINUED)*

| Species                  | Family      |
|--------------------------|-------------|
| *Colostethus sp.*        | *Dendrobatidae* |
| *Epipedobates boulengeri*| *Dendrobatidae* |
| *Hyloxalus awa*          | *Dendrobatidae* |
| *Oophaga sylvatica*      | *Dendrobatidae* |
| *Agalychnis spurrelli*   | *Hylidae*    |
| *Hypsiboas boans*        | *Hylidae*    |
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- *Scinax quinquefasciatus* (JB) - Hylidae
- *Smilisca phaeota* (JB) - Hylidae
- *Smilisca phaeota* (JB) - Hylidae
- *Leptodactylus labrosus* (JB) - Leptodactylidae
- *Leptodactylus rhodomerus* (JB) - Leptodactylidae
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*Pristimantis muricatus* (JB) - STRABOMANTIDAE

*Pristimantis parvillus* (juvenile) (JB) - STRABOMANTIDAE

*Pristimantis rosadoi* (CA) - STRABOMANTIDAE

*Pristimantis sp.* (JB) - STRABOMANTIDAE

*Pristimantis subsigillatus* (JB) - STRABOMANTIDAE

*Pristimantis subsigillatus* (JB) - STRABOMANTIDAE
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Pristimantis walkeri (JB) - STRABOMANTIDAE

Bolitoglossa biseriata (MO) - PLETHODONTIDAE

Bolitoglossa biseriata (MO) - PLETHODONTIDAE

Bolitoglossa sima (JB) - PLETHODONTIDAE

Caecilia nigricans (JB) - CAECILIDAE

Caecilia sp. (JB) - CAECILIDAE
APPENDIX 3. Amphibians and Reptiles from Bilsa Biological Station, northwestern Ecuador. Photographers: J.S. Bermingham (JB), C.F. Aulestia-Obanda (CA), H. M. Ortega-Andrade (MO), E. Neuschulz (EN) and Christian Pascar (CP). (CONTINUED)
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Lepidoblepharis buchwaldi (JB) - Sphaerodactylidae

Lepidoblepharis grandis (JB) - Sphaerodactylidae

Lepidoblepharis ruthveni (JB) - Sphaerodactylidae

Thecadactylus rapicauda (MO) - Phyllodactylidae

Alopoglossus festae (MO) - Gymnophthalmidae

Anadia rhombifera (MO) - Gymnophthalmidae
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*Enyalioides oshaughnessyi* (JB) - Hoploceridae

*Anolis biporcatus* (JB) - Polychrotidae

*Anolis biporcatus* (JB) - Polychrotidae

*Anolis chocorum* (JB) - Polychrotidae

*Anolis fraseri* (JB) - Polychrotidae

*Anolis fraseri* (JB) - Polychrotidae
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Anolis princeps (JB) - Polychrotidae

Anolis lyra (male) (JB) - Polychrotidae

Polychrus gutturosus (CA) - Polychrotidae

Ameiva septemlineata (JB) - Teiidae

Ameiva septemlineata (JB) - Teiidae

Boa constrictor imperator (JB) - Boidae
Appendix 3. Amphibians and Reptiles from Bilsa Biological Station, northwestern Ecuador. Photographers: J.S. Bermingham (JB), C.F. Aulestia-Obanda (CA), H. M. Ortega-Andrade (MO), E. Neuschulz (EN) and Christian Pascar (CP). (Continued)

Atractus sp. (cf. microrhynchus) (MO) - Colubridae

Atractus sp. (cf. melas) (JB) - Colubridae

Chironius grandisquamis (JB) - Colubridae

Chironius monticola (JB) - Colubridae

Chironius sp. (JB) - Colubridae

Clelia clelia (JB) - Colubridae
APPENDIX 3. Amphibians and Reptiles from Bilisa Biological Station, northwestern Ecuador. Photographers: J.S. Bermingham (JB), C.F. Aulestia-Obanda (CA), H. M. Ortega-Andrade (MO), E. Neuschulz (EN) and Christian Paucar (CP). (CONTINUED)
Appendix 3. Amphibians and Reptiles from Bilsa Biological Station, northwestern Ecuador. Photographers: J.S. Bermingham (JB), C.F. Aulestia-Obanda (CA), H. M. Ortega-Andrade (MO), E. Neuschulz (EN) and Christian Pascar (CP). (Continued)

*Imantodes inornatus* (JB) - Colubridae

*Imantodes cenchoa* (JB) - Colubridae

*Dipsas andiana* (JB) - Colubridae

*Dipsas gracilis* (MO) - Colubridae

*Erythrolamprus mimus micrurus* (JB) - Colubridae

*Imantodes inornatus* (JB) - Colubridae
APPENDIX 3. Amphibians and Reptiles from Bilsa Biological Station, northwestern Ecuador. Photographers: J.S. Bermingham (JB), C.F. Aulestia-Obanda (CA), H. M. Ortega-Andrade (MO), E. Neuschulz (EN) and Christian Paucar (CP). (CONTINUED)

Leptodeira septentrionalis (juvenile) (MO) - Colubridae

Leptodeira septentrionalis (MO) - Colubridae

Leptophis ahaetulla (JB) - Colubridae

Leptophis riveti (CA) - Colubridae

Liophis epinephelus (JB) - Colubridae

Mastigodryas heathii (JB) - Colubridae
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Mastigodryas pulchriceps (MO) - Colubridae

Unidentified sp. (JB) - Colubridae

Ninia atrata (JB) - Colubridae

Oxybelis brevirostris (JB) - Colubridae

Oxyrophus petola sebae (JB) - Colubridae

Plicercus euryzonus (JB) - Colubridae
APPENDIX 3. Amphibians and Reptiles from Bilsa Biological Station, northwestern Ecuador. Photographers: J.S. Bermingham (JB), C.F. Aulestia-Obanda (CA), H. M. Ortega-Andrade (MO), E. Neuschulz (EN) and Christian Pascar (CP). (CONTINUED)

*Pseustes shropshirei* (JB) - *Colubridae*

*Rhadinea cf. decorata* (JB) - *Colubridae*

*Sibon* sp. (JB) - *Colubridae*

*Sibon nebulata* (JB) - *Colubridae*

*Stenorrhina degenhardtii* (JB) - *Colubridae*

*Tantilla melanocephala* (JB) - *Colubridae*
APPENDIX 3. Amphibians and Reptiles from Bilsa Biological Station, northwestern Ecuador. Photographers: J.S. Bermingham (JB), C.F. Aulestia-Obanda (CA), H. M. Ortega-Andrade (MO), E. Neuschulz (EN) and Christian Pascua (CP). (CONTINUED)
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*Trachyboa boulengeri* (head) (CP) - **Tropidophiidae**

*Bothriechis schlegelii* (JB) - **Viperidae**

*Bothriechis schlegelii* (JB) - **Viperidae**

*Lachesis acrochorda* (JB) - **Viperidae**

*Lachesis acrochorda* (juvenile) (JB) - **Viperidae**