RANGE EXTENSION AND NATURAL HISTORY OBSERVATIONS FOR THE SMOKY BAT
(Amorphochilus schnablii)

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ABSTRACT. The narrow Pacific coastal region west of the Andes Mountains in South America is a hotspot of endemism, including at least seven bat species. One of the least known species from this region is Amorphochilus schnablii, a small, thumbless bat in the family Furipteridae (Order Chiroptera). There are few capture records and museum specimens for this species, leaving an incomplete picture of its geographic range and life history traits. Here we present a revised distribution map and demographic data based on captures of A. schnablii from a colony in southwestern Ecuador. This colony is located 30km farther north than any other known colony and contains twice as many individuals as previously reported colonies. A total of 55 bats were captured in February and September of 2010-2011. Standard measurements were taken from all individuals and adult females were assessed for reproductive condition. By combining these new demographic data with previous records, we examined annual reproductive trends, which suggests a pattern of seasonal monoestry. Parturition appears to be timed to occur just before the onset of the rainy season in December or January, a pattern observed in many other Neotropical insectivorous bats. More captures are needed to better understand the distribution, ecology, and life history of A. schnablii, but given their rareness, survey data are difficult to obtain.

RESUMEN. Extensión de rango geográfico y observaciones sobre la historia natural para el murciélago ahumado, Amorphochilus schnablii. La estrecha región costera del Pacífico al oeste de las montañas de los Andes en América del Sur es un punto de acceso al endemismo, que incluye al menos siete especies de murciélagos. Una de las especies menos conocidas de esta región es Amorphochilus schnablii, un pequeño murciélago de la familia Furipteridae (Orden Chiroptera). Hay pocos registros de captura y especímenes de museo para esta especie, lo que deja una imagen incompleta de su rango geográfico y sus rasgos de historia de vida. Aquí presentamos un mapa de distribución revisado y datos demográficos basados en capturas de A. schnablii de una colonia en suroeste de Ecuador. Esta colonia se ubica 30km más al norte que cualquier otra colonia conocida y contiene el doble de individuos que las colonias documentadas anteriormente. Un total de 55 murciélagos fueron capturados en febrero y septiembre de 2010-2011. Se tomaron medidas estándar de todos los individuos y se evaluó la condición reproductiva de las hembras adultas. Al combinar estos nuevos datos demográficos con registros previos, examinamos las tendencias reproductivas anuales, lo que sugiere un patrón de monoestasis estacional. El parto parece estar programado para ocurrir justo antes del inicio de la temporada de lluvias en diciembre o enero, un patrón observado en muchos otros murciélagos insectívoros neotropicales. Se necesitan más capturas para comprender mejor la distribución, la ecología y la historia de vida de A. schnablii, pero dada su rareza, los datos de censo son difíciles de obtener.
INTRODUCTION

Small, nocturnal species inhabiting restricted geographic ranges tend to be poorly known. Such is the case for the smoky bat, *Amorphochilus schnablii* (Peters, 1877; Mammalia: Chiroptera), which is endemic to the narrow Pacific coastal plain west of the Andes Mountains in South America. Unlike *Furipterus horrens*, the only other member of family Furipteridae (Gardner 2008; Novaes et al. 2012), *A. schnablii* is poorly represented in the scientific literature. Our knowledge of *A. schnablii* is based on very few published records of observation or capture, leaving an incomplete picture of distribution and life history traits. Through a literature and specimen search we found mention of approximately 35 capture locations in three countries over more than 100 years, with fewer than 200 specimens reported in museum collections around the world (VertNet, http://vertnet.org). Although the latest assessment by the International Union for the Conservation of Nature’s (IUCN) Red List of Threatened Species downgraded *A. schnablii* from “Endangered” to “Vulnerable”, habitat destruction is still considered a significant threat (Velazco et al. 2015).

Most mentions of *Amorphochilus schnablii* in the literature are limited to brief descriptions of physical traits. *A. schnablii* is a rather diminutive bat with dark brown or slate-gray fur and enlarged ears that curve around the eyes (Fischer 1978; Gardner 2008; Fig. 1). Wart-like outgrowths on the mouth and lips are key characteristics distinguishing *A. schnablii* from *F. horrens*. Both species have a greatly reduced thumb and abdominal mammary glands, unique features among bats (Ibáñez 1985; Bahlman et al. 2016). In *A. schnablii*, nasal appendages are absent and the tail terminates anterior to the trailing edge of the uropatagium. This species is sexually dimorphic with females having larger wings than males (Ibáñez 1985; Gardner 2008).

A single fossil record from the Ica Province of Peru places *A. schnablii* within the Pacific coastal plain of South America as early as the Miocene Era (Morgan & Czaplewski 1999), approximately 23 to 5.3 million years ago. This is an extremely arid region due to uplift of the Andes millions of years ago, which is thought to have limited dispersal and altered weather patterns (Parker & Carr 1992; Patterson et al. 1992; Morgan & Czaplewski 1999). These changes promoted adaptation and ultimately endemism in a variety of taxa, including bats, butterflies, plants (Patterson et al. 1992), and rodents (Patterson et al. 2012), many of which are considered threatened (Parker & Carr 1992). The southern end of the range of the smoky bat is known to extend from the Atacama Desert in northern Chile through the Peruvian Desert (Ortiz De La Puente 1951; Fischer 1978; Koopman 1978), which together form a continuous belt that remains dry and mild throughout most of the year due to the Humboldt Current and the topography of the coast (Rundel et al. 1991). In the north, the range extends into northern Peru and southern Ecuador (Ibáñez 1985; Gardner 2008; Tirira et al. 2012), including Isla Puná (Allen 1914), where the habitat transitions to dry forest (Tirira et al. 2012) and a brief rainy season occurs from approximately December to May (Ibáñez 1985; Graham 1987). El Niño/Southern Oscillation (ENSO) cycles may periodically alter these weather patterns, typically causing a drastic increase in rainfall (Jaksic 2001).

While endemic to a narrow range, *A. schnablii* exhibits a generalist roosting strategy. Colonies have been recorded in a mix of natural and anthropogenic structures, including caves, rock fissures, abandoned buildings, sugar mills, culverts, irrigation tunnels, and cellars. Previously reported colonies range from 5 and 300 individuals and are usually of mixed sex (Ortiz De La Puente 1951; Fischer 1978; Ibáñez 1985; Aragón A. & Aguirre Q. 2014; Falcão et al. 2015; Velazco et al. 2015). Colonies may include other species, such as *Glossophaga soricina valens* (Ortiz De La Puente 1951), a similarly-sized, nectarivorous chiropteran, although Ibáñez (1985) found a monospecific colony in southern Ecuador. Colonies are typically found at low to mid elevations between five and 2000m (Tirira et al. 2012), where development and conversion of habitat for agriculture is prominent (Velazco et al. 2015). Individuals have also been captured at higher elevations and along inter-Andean valleys in the Cajamarca Province of Peru, which are not represented in the most recent IUCN range map (Fig. 2). One specimen captured at 4 000m elevation in the Piura Province of Peru (Museum of Vertebrate Zoology at Berkeley Specimen 135616) should most likely be considered an incidental vagrant and not representative of the
Fig. 1. *Amorphochilus schnablii*, adult specimen captured and released at the largest colony documented, coastal Ecuador.

Elevation range typically occupied by this species. Recent documentation of *A. schnablii* echolocation calls and subsequent acoustic recording suggests that the species may be more abundant than previously thought in southwestern Peru (Falcão et al. 2015; Velazco et al. 2015), partially contributing to the species’ downgraded IUCN Red List status in 2015.

Analysis of stomach contents and guano from *A. schnablii* has produced only lepidopterans, suggesting that this species feeds exclusively on moths (Ortiz De La Puente 1951; Fischer 1978; Ibáñez 1985), although dipterans are abundant and Fischer (1978) suggests they might be considered a potential food source. Rainfall is a well-documented driver of insect abundance in tropical regions (Janzen & Schoener 1968; Wolda 1978; Graham 1987), which in turn is thought to influence the timing of reproduction of bats, such that parturition occurs just before the onset of the rainy season (December to May). Lactation, the most energetically costly part of reproduction, then coincides with the peak of the wet season when food is most abundant (Fleming et al. 1972). Despite a lack of published demographic data, Graham (1987) suggests that this species is monoestrous, breeding once per year during the Peruvian rainy season.

In this study, we present valuable demographic data based on seasonal observations and captures of *A. schnablii* from one colony in southwestern Ecuador as well as a revised distribution map based on our field observations and literature and specimen searches.

**MATERIALS AND METHODS**

**Study Site**

In 1998, a small colony of *A. schnablii* was discovered in an old building in Rio Chico, Manabi Province, Ecuador. The building is approximately 300 m from the shoreline at the Hosteria Piñeros de Pata Azules (01°36'29.5"S, 80°50'23.5"W). This colony was not seen after 2000, but a second colony was discovered in 2010 on the same property. The bats were found roosting in an abandoned concrete building situated adjacent to an isolated patch of mangrove swamp in a region dominated by dry coastal forest. The building is approximately 100 m from the Pacific shoreline and at 5 m elevation. Towards the end of 2011, the roof of this structure collapsed and the entire colony emigrated to an unknown location. Similar structures within a 0.5km radius have been surveyed as potential sites for re-establishment, but without positive results. The location of this colony at the time of the study represents a northerly range extension of nearly 30 km beyond the previously reported northernmost location in Manglaralto (Tirira et al. 2012; Fig. 2).

**Data Collection and Analysis**

In February 2010, September 2010, and February 2011, roosting *Amorphochilus schnablii* were captured using a hand net during daylight hours from the abandoned building in Rio Chico. Captured individuals were placed in separate cloth bags, processed, and released within one hour. Females with pups attached were kept together in their own cloth bag until being briefly separated for processing; they were reunited prior to release. All individuals were examined for sex, age, and reproductive status. Juveniles were distinguished from adults by the presence of an epiphyseal gap at the ends of the phalanges. Standard morphometric measurements taken from all bats include forearm, tail, head, and total length. Bats captured in February 2010 and 2011 were also measured for tibia, foot, and ear length. Non-parametric statistical tests (Mann-Whitney U and Kruskal-Wallis) were used to compare measurement data between
Fig. 2. Occurrence records for *Amorphochilus schnablii* in Ecuador, Peru, and Chile. Past capture records based on the literature and museum specimens are indicated by black circles (see Appendix 1), a fossil discovery in Peru by the yellow triangle (Morgan & Czaplewski 1999), and the study location by the red star. The hashed area shows the distribution of *A. schnablii* according to the 2015 International Union for the Conservation of Nature (IUCN) species report.

Fig. 3. One of a series of photographs taken at the noon hour within a span of one minute in an abandoned structure in southern Manabí Province, Ecuador, 30 September 2010. Together, the set of images allowed the determination of minimum colony size.
the two juvenile cohorts and between the juveniles and adults. All statistical tests were conducted in R version 3.2.2 (R Core Team 2017).

Lactation was determined by the presence of a pup and/or the appearance of the nipple. In September 2010, females were not palpated to determine whether they were pregnant. Data from February 2010 and 2011 were pooled to calculate the percent of females lactating in February and combined with demographic data from Graham (1987) and Ibáñez (1985) to examine annual reproductive trends. An estimate of colony size in February 2011 was determined by visual examination of digital still images taken during daytime roosting (Fig. 3).

This study was conducted under Permit No. 005-2015-GC-DPAM-MAE issued by the Ministerio del Ambiente of Ecuador.

RESULTS
Captures
A total of 55 individuals were captured and processed during three trapping events. Although individuals were not marked, the size of the colony and the randomness of samples make the likelihood of overlapping captures quite low. Adults made up less than half of all captures (n=23), while the ratio of males to females was nearly even (56% males). A higher proportion of adult females compared to adult males and juvenile males compared to juvenile females was captured throughout the study. Nine non-reproductive females were captured in September 2010. One of two females was found lactating in February 2010 and four of five females were lactating in February 2011, resulting in a combined lactation rate of 71%. All females found carrying young (n=5) were captured in February and had a maximum of one pup attached. Using digital images taken during roosting, colony size in September 2010 was determined to exceed 650 individuals (Fig. 3).

Photographic and field observations as well as captures of only A. schnablii during trapping events suggest a monospecific colony.

Measurements from adults mostly fell within the range of measurements reported in the literature, except for some smaller adult individuals. Forearm length showed the least variation and was the most consistent with previously reported measurements (Table 1). Adult measurements did not vary significantly between capture events, except for total length (TL; Kruskal-Wallis test, forearm p=0.87; tail p=0.99; TL p=0.03). Juveniles captured in September 2010 (n=21) were significantly larger than those captured in February 2011 (n=12) in all measurements: forearm length (U=3, p < 0.001), tail length (U=21.5, p < 0.001), and total length (U=24, p < 0.001). The forearms of juveniles caught in September 2010 were not significantly different in size compared to those of adults captured in 2010 and 2011 (H=2.96, p=0.23), while juveniles from February 2011 had significantly smaller forearm, total, and tail lengths (all p < 0.001) than adults.

Literature Review
Demographic data from the literature, combined with data from our study, provide at least one data point for pregnancy (n=7) and/or lactation (n=3) in eight of 12 months (Fig. 4). Graham (1987) reported juveniles from one site in Peru in April and pregnant females in June, August, and October. The pregnant females from August were noted to have small embryos. Ibáñez (1985) captured individuals from a colony in Ecuador in November 1981, and found no juveniles present, 8 of 10 females pregnant with fetuses measuring 2-6 mm from crown to rump, and none lactating.

DISCUSSION
We have confirmed that Amorphochilus schnablii occurs farther north along the Ecuadorian coast than previous records indicated. The colony we discovered in Rio Chico represents a northerly range extension of approximately 30 km. In addition, colony size potential for the species is, based on our observations, two times greater than the largest colony previously reported (Ibáñez 1985). We are confident that this was a monospecific colony of at least 650 individuals, comprised of males and females of both age classes. The presence of a large colony on the northerly edge of the geographic range suggests that A. schnablii could be present even farther to the north if habitat requirements are met, as models from Tirira et al. (2012) propose. The use of an abandoned building by this colony further supports previous reports of A. schnablii roosting in a variety of natural and anthropogenic structures.

Previous studies on the timing of reproduction in A. schnablii have proposed a pattern of seasonal monoestry, with parturition occurring during the rainy season (Ibáñez 1985; Graham 1987). This study supports these claims by adding several key data points to better represent the entire reproductive cycle (Fig. 4). Based on the presence of juveniles and their average sizes as well as the proportion of pregnant or lactating females at different times of the year, it appears that this species does indeed exhibit seasonal monoestry. No pregnant females were captured in May, but were captured in July and August with small embryos. The one pregnant individual reported from June likely represents an
Table 1

Measurements for forearm, tail, head, and total length from the Rio Chico colony from February 2010 and 2011 (combined) and September 2010, compared to the range of measurements reported in the literature (References). Data are shown as averages (mean) and minimum and maximum measurements (range) in millimeters, reported separately for juveniles and adults.

|                | February Adults (n=10) | February Juveniles (n=12) | September Adults (n=15) | September Juveniles (n=20) | References |
|----------------|------------------------|---------------------------|-------------------------|---------------------------|------------|
|                | Length                 | Mean                      | Range                   | Mean                      | Range      |
| Forearm        | 36.1                   | (35.0-37.6)               | 30.3                    | (25.9-34.6)               | 36.3       | (34.9-38.2) |
| Tail           | 24.9                   | (19.1-27.5)               | 17.7                    | (11.0-25.1)               | 25.1       | (20.1-30.0) |
| Head           | 13.5                   | (12.6-16.0)               | 11.8                    | (10.6-13.1)               | 13.4       | (11.7-14.0) |
| Total          | 37.5                   | (32.1-43.3)               | 29.0                    | (24.0-34.8)               | 34.6       | (32.4-39.1) |

Fig. 4. Change in percentage of females pregnant (filled diamonds) or lactating (open circles) over the course of a year based on data collected by Ibáñez (1985), Graham (1987), and this study. Bars at the top of the graph indicate presence of juveniles.

outlier (Graham 1987). The high percentage of pregnant females from August to November (Graham 1987; Ibáñez 1985), our capture of lactating females and mothers carrying their pups in February, and the smaller size of juveniles captured in February compared to those from September all suggest a birth peak in December or January, at the onset of the rainy season. Timing parturition to occur just before the rainy season is a pattern observed in many tropical insectivorous bats (Racey & Entwistle 2000), including several found in Central America (Fleming et al. 1972) and Thyroptera tricolor from the closely related Thyropteridae family (Graham 1987). Lepidopterans are the main prey for A. schnablui (Ibáñez 1985) and although information on insect abundance along the western coast of South America is scarce, changes in abundance are generally thought to mirror changes in rainfall (Janzen & Schoener 1968; Wolda 1978; Graham 1987).

Additional captures of A. schnablui throughout the course of the year will be necessary to more accurately define the details of the reproductive cycle of this species and to better understand the differences in the timing of reproduction throughout its range. Improved understanding of their ecology and roost preferences will enable better protection

Smaller bat species tend to have shorter gestation periods of about two months (Racey & Entwistle 2000), which would suggest that A. schnablui is not a highly synchronous breeder throughout its range. For example, (Ibáñez 1985) found pregnant females with small embryos in November in Ecuador, while Graham (1987) provides records of pregnant females with small embryos in August in Peru. Bats most likely respond to environmental cues such as temperature, rainfall, and insect abundance; differences in these factors between studies, which occurred across decades and several degrees of latitude, could account for the observed length of the gestation period from August to November. In addition, predictable weather patterns were disrupted during our study in relation to ENSO events.
for this vulnerable species. While the variety of roost types used by *A. schnablii* suggests adaptability to human intrusion, bats living in or near humans are always vulnerable to human predation or disturbance, as seen in the recent burning of a large roost site in northern Peru (Velazo et al. 2015). Anthropogenic structures may also be less stable over time, as witnessed with the collapse of the roof of the building at Rio Chico. Protection of key habitats and roost sites along the western coast of South America will be important for conserving and protecting *A. schnablii* as well as the many other species endemic to this unique region of the world.

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