Evolutionary Systematics. 4 2020, 35–43 | DOI 10.3897/evolsyst.4.49377

EVOLUTIONARY SYSTEMATICS

Rare or misidentified? On the external identification of the neglected *Artibeus inopinatus* Davis & Carter, 1964 (Chiroptera, Phyllostomidae) in Honduras

Manfredo Alejandro Turcios-Casco[1,2], Hefer Daniel Ávila-Palma[3], Eduardo Javier Ordoñez Trejo[3], José Alejandro Soler Orellana[3,4], Diego Iván Ordoñez Mazier[3], David Eduardo Meza-Flores[5], Alejandro Velásquez[4]

1 *Departamento de Vida Silvestre, Instituto Nacional de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre (ICF), Francisco Morazán, Honduras*
2 *Biological Institute, Tomsk State University (TSU), 36 Lenin Ave., Tomsk, Russia*
3 *Escuela de Biología, Facultad de Ciencias, Universidad Nacional Autónoma de Honduras (UNAH), Boulevard Suyapa, Francisco Morazán, Honduras*
4 *Colección Privada y Centro de Rescate de Fauna Silvestre El Ocotal, Sabanagrande, Francisco Morazán, Honduras*
5 *Asociación de Investigación para el Desarrollo Ecológico y Socioeconómico (ASIDE), Barrio Las Delicias, El Progreso, Yoro, Honduras*

http://zoobank.org/FA67143C-A3C4-48D5-8781-7C8100AE15D5

Corresponding author: *Manfredo Alejandro Turcios-Casco* (manturcios21@gmail.com)

Academic editor: *Alexander Haas* ♦ **Received** 13 December 2019 ♦ **Accepted** 4 February 2020 ♦ **Published** 20 February 2020

Abstract

For years, the identification of *Artibeus* species has been controversial due to the overlap of morphometric characteristics between species. From February 2015 to September 2019, we sampled 25 sites in 10 departments of Honduras, and captured 81 *Artibeus* individuals using mist-nets. We determined the morphometric measurements that may be helpful in the identification of adult individuals of the Honduran Fruit-eating Bat, *Artibeus inopinatus*, in the field. We analyzed 648 morphometric measurements using a linear discriminant analysis, and determined that the forearm length, third metacarpal length, the length of the second phalanx of digit III, and body length are the main characteristics for the external identification of *A. inopinatus*.

Key Words

Artibeus, Central America, Honduran Fruit-eating Bat, Stenodermatinae, taxonomy

Introduction

Phyllostomidae is a family of bats known to be endemic to the American continent, occurring from the southwestern United States to northern Argentina (Redondo et al. 2008; Reid 2009). The Neotropical genus *Artibeus* (sensu stricto) within the Stenodermatinae subfamily comprises 12 recognized species and is considered as a recognized representative of the assemblage of the Neotropical chiropteran fauna (Lim 1997; Larsen et al. 2010). *Artibeus* (sensu lato), supported by morphological analysis, was traditionally divided into two taxa according to body size, *Artibeus* (large species) and *Dermanura* (small species) (Marchán-Rivadeneira et al. 2010), but Owen (1991) described *Koopmania* from a previously known species as *A. concolor*. Thus, many authors have systematic and taxonomic criteria to support the division of the genus into three genera (Larsen et al. 2007; Hoofer et al. 2008; Redondo et al. 2008; Larsen et al. 2010). In this work, we consider *Dermanura* to be a distinct genus from *Artibeus* following Hoofer et al. (2008) and not Cirranello et al. (2016), and we follow Wilson and

Mittermeier (2019) for the taxonomy and nomenclature of the other taxa cited here.

Among the 111 bat species recorded in Honduras (Ávila-Palma et al. 2019; Turcios-Casco et al. 2020), *Artibeus* is a genus with a controversy of using morphometric characteristics for the species identification in the country. For example, Davis (1970), mentioned that *Artibeus inopinatus* might be confused with subspecies of *A. jamaicensis paulus* and *A. j. richardsoni* on the Pacific slope of Honduras, due to a substantial geographical variation presented by *A. jamaicensis*, which also occurs sympatrically with *A. lituratus*. Moreover, the length of the forearm (morphometric measurement usually used for the identification of these species in Honduras) may not be the most useful characteristic for identifying *Artibeus* species (Davis 1970). After Davis and Carter (1964), Davis (1970, 1984), and Dolan and Carter (1979), there are no systematic studies that could clarify the morphometric characteristics for the identification of these species in Honduras, due to the overlap in morphometrical characteristics, especially forearm length.

The objective of this study was to determine the main characteristics for the external identification of *A. inopinatus* in order to clarify its controversial identification in the field. We hypothesized that external morphometric measurements can be used to identify *A. inopinatus* in the field despite any overlap. Additionally, we give comments of the distribution, ecology, and morphology for *A. inopinatus*.

Materials and methods

Study areas

From February 2015 to September 2019, we sampled 25 sites (35–1785 m asl), and bats were captured within a variety of life zones based on Holdridge (1967). All the studied areas, localities, coordinates, and life zones are given in Suppl. material 1 and the localities for each species are presented in Fig. 1. We sampled ten out of the 18 departments in the country – central: Comayagua and Francisco Morazán; southern: Valle and Choluteca; western: Copán, Intibucá and Santa Bárbara; northern: Atlántida; eastern: Gracias a Dios and Olancho.

Sampling, bat identification, and morphometrical data

We used mist-nets of standard measurements (12×2.5 m) with a 35 mm mesh. They were placed based on the criteria proposed by Kunz and Kurta (1988) for vegetation, topography, and bodies of water and were deployed in open fields and inside forest canopy, in human settlements such as cities, suburbs, villages, small hamlets, creeks and river basins (both dry and with water flowing), seasonal ponds, areas used for coffee, cacao, or corn cropping, mango and banana groves, grasslands for cattle, and cave entrances. A Mitutoyo 506–675 dial caliper, was used for the external measurements to the nearest 0.01 mm, and a Pesola scale of 100 g was used for measuring body mass. Biological age was determined based on the verification of the ossification of the joints of the forearm in the field (Brunet-Rossinni and Wilkinson 2009). Sampling effort was calculated as the area of the mist-nets times the number of hours the mist-nets remained opened for each night (Straube and Bianconi 2002).

We identified *A. inopinatus* based on Davis (1970) and Webster and Jones (1983) following these characteristics: small in comparison with *A. jamaicensis* and *A. lituratus*, with a forearm length near 52.0 mm (48.0–53.0); body mass of 29.3 g (24.7–35.9); fringe of hairs in the uropatagium; length of the third metacarpal of 46.4 mm (45.6–47.0); length of the first phalanx of digit III of 14.8 (14.1–15.4); and the length of the second phalanx of digit III of 24.0 (23.0–24.7). For the identification of *A. jamaicensis* and *A. lituratus* we followed Timm et al. (1999), Medellín et al. (2008), and Medina-Fitoria (2014). In addition, seven external measurements (mm) and body mass (W), following Simmons and Voss (1998) with modifications of Srinivasulu et al. (2010) and Velazco and Cadenillas (2011), were taken on live, adult, and non-pregnant bats during the fieldworks:

Body length (*BL*) = Distance from the tip of the snout to the distal part of the pelvis
Forearm length (*FA*) = Distance from the elbow (tip of the olecranon process) to the wrist (including the carpals)
Third metacarpal length (*3mt*) = Distance from the joint of the wrist (carpal bones) with the third metacarpal to the metacarpophalangeal joint of third finger
Length of the first phalanx of digit III (*1ph*) = Distance from the first phalanx to the joint of second phalanx of third finger
Length of the second phalanx of digit III (*2ph*) = Distance from the second phalanx to the joint of third phalanx of third finger
Length of the third phalanx of digit III (*3ph*) = Distance from the third phalanx to the distal or free part of third finger including the cartilaginous tip
Calcaneus length (*Ca*) = Distance from the base of the calcaneus bone to the distal part of it that is extended to the uropatagium.

We analyzed the external measurements of *Artibeus* species using the package MASS with the statistical software R 3.4.2 (R Core Team 2015) to make a linear discriminant analysis and determine which external characteristics are the most useful for the identification of the species of *Artibeus*. All the measurements were standardized with normal logarithm, and the external characteristics are provided in Table 1. Two coefficients of linear discriminant functions (Table 2), LD1 and LD2, combined all the values of the measurements to determine which characteristics for the external identification of *A. inopinatus* may be used. Finally, a one-way ANOVA analysis was done with the same software for each species to determine the variance of each of the measurements.

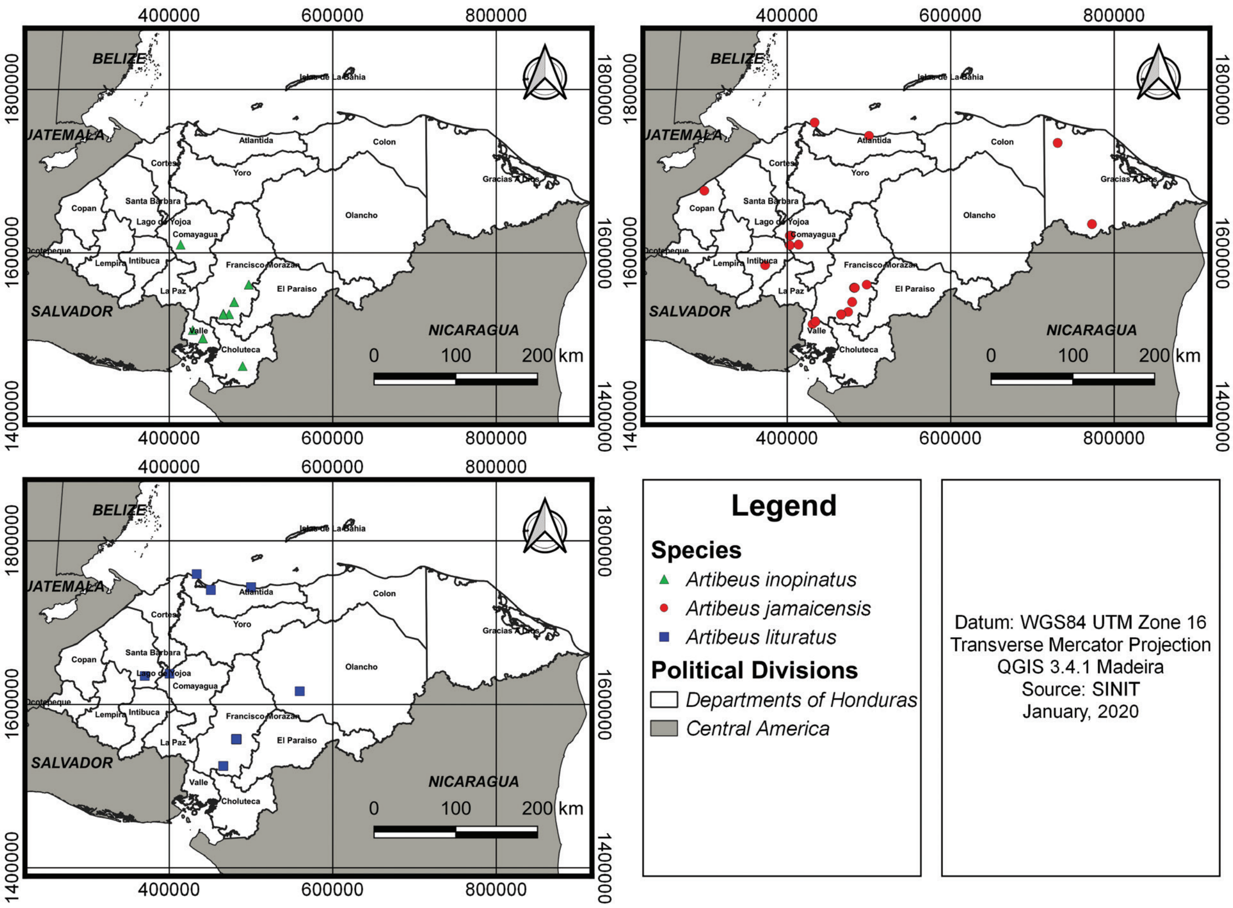

Figure 1. Localities in which the three species of *Artibeus* were recorded from February 2015 to September 2019. Notice the extension of the distribution of *A. inopinatus* to different localities in northern Francisco Morazán and Comayagua. These records represent a distribution extension because it was only known in southern Honduras including El Paraíso (GBIF.org 2019).

Table 1. Standardized measurements with normal logarithm of 81 individuals of *Artibeus* species recorded in Honduras from February 2015 to September 2019.

No.	Species	Ca	FA	BL	3mt	1ph	2ph	3ph	W
1	*Artibeus inopinatus*	-0.30	-2.43	-2.85	-1.92	-1.60	-2.26	-1.78	-2.41
2	*Artibeus inopinatus*	-0.32	-2.28	-2.08	-2.25	-1.73	-2.33	-1.58	-2.12
3	*Artibeus inopinatus*	-0.87	-2.16	-0.54	-3.21	-2.43	-2.36	-2.17	-2.08
4	*Artibeus inopinatus*	-1.27	-2.04	-0.88	-1.29	-1.24	-1.75	-1.11	-1.27
5	*Artibeus inopinatus*	-1.35	-2.01	-0.84	-0.97	-1.06	-2.72	-0.23	-1.37
6	*Artibeus inopinatus*	-2.68	-1.98	-0.28	-2.84	-0.26	-2.34	-2.89	-2.02
7	*Artibeus inopinatus*	-1.39	-1.97	-1.33	-1.19	-0.56	-0.89	-1.37	-1.36
8	*Artibeus inopinatus*	-0.38	-1.91	-0.46	-0.96	-1.05	-1.05	-0.08	-1.05
9	*Artibeus inopinatus*	-1.47	-1.89	-0.59	-0.99	-1.46	-0.88	-0.30	-0.52
10	*Artibeus inopinatus*	-1.68	-1.89	-1.11	-1.14	-1.50	-0.96	-0.24	-1.49
11	*Artibeus inopinatus*	-1.42	-1.88	-0.71	-1.00	-1.00	-1.53	-0.25	-1.27
12	*Artibeus inopinatus*	-0.11	-1.86	-1.40	-1.27	-0.54	-0.58	-0.24	-0.89
13	*Artibeus inopinatus*	0.70	-1.74	-1.41	-2.34	-2.11	-2.20	-1.54	-2.12
14	*Artibeus inopinatus*	-1.41	-1.74	-1.70	-1.90	-1.55	-1.40	-1.07	-1.83
15	*Artibeus inopinatus*	-1.41	-1.70	0.01	-0.98	-0.57	-1.41	0.18	-0.70
16	*Artibeus inopinatus*	-0.34	-1.59	-1.74	-1.04	-0.86	-0.53	-0.44	-1.60
17	*Artibeus inopinatus*	-0.23	-1.59	-1.11	-0.97	-1.01	-0.92	-0.23	-1.13
18	*Artibeus inopinatus*	-1.42	-1.59	-1.40	-0.98	-0.44	-1.74	0.04	-1.65
19	*Artibeus inopinatus*	-1.90	-1.58	-1.73	-1.04	-0.87	-0.54	-0.25	-0.61
20	*Artibeus inopinatus*	0.16	-1.56	-2.30	-1.30	-0.56	-0.90	-0.47	-1.51
21	*Artibeus jamaicensis*	-1.43	-1.02	-0.72	-0.31	-0.83	-0.41	-0.26	-0.61
22	*Artibeus jamaicensis*	0.68	-0.91	-2.01	-0.48	-0.46	-0.48	0.17	-1.03
23	*Artibeus jamaicensis*	-0.32	-0.89	-0.55	-1.00	-0.86	-1.02	0.67	-0.34
24	*Artibeus jamaicensis*	-1.15	-0.58	-0.89	-0.74	-1.03	-0.88	-0.23	-0.70

No.	Species	Ca	FA	BL	3mt	1ph	2ph	3ph	W
25	*Artibeus jamaicensis*	-0.51	-0.43	-1.56	-0.82	0.21	0.03	0.56	-0.56
26	*Artibeus jamaicensis*	-0.20	-0.20	-0.22	0.51	0.01	0.45	0.73	0.29
27	*Artibeus jamaicensis*	1.01	-0.19	-1.67	-0.08	0.66	-0.04	0.63	-0.42
28	*Artibeus jamaicensis*	1.21	-0.16	-1.34	0.29	0.18	0.48	0.69	-0.66
29	*Artibeus jamaicensis*	-0.28	-0.16	0.00	-0.11	-0.47	-0.50	0.31	-0.61
30	*Artibeus jamaicensis*	-0.37	-0.15	-0.58	0.27	-0.39	0.40	0.30	0.33
31	*Artibeus jamaicensis*	-0.31	-0.14	0.30	0.83	-0.86	-0.17	0.30	-0.26
32	*Artibeus jamaicensis*	1.21	-0.12	0.09	0.52	0.24	0.35	0.21	0.14
33	*Artibeus jamaicensis*	2.36	-0.11	-0.32	0.19	-1.00	-0.83	-1.03	0.89
34	*Artibeus jamaicensis*	0.67	-0.10	0.30	0.59	0.22	-0.38	0.82	0.40
35	*Artibeus jamaicensis*	-0.04	-0.08	-2.28	0.30	1.13	1.23	0.76	0.05
36	*Artibeus jamaicensis*	0.70	0.13	1.26	0.56	0.06	0.42	0.68	0.26
37	*Artibeus jamaicensis*	1.07	0.16	-0.80	0.30	0.00	0.45	0.66	-0.80
38	*Artibeus jamaicensis*	-0.23	0.18	-0.01	0.21	0.03	0.50	0.83	0.76
39	*Artibeus jamaicensis*	-0.40	0.19	0.00	0.78	0.04	-0.02	0.25	0.29
40	*Artibeus jamaicensis*	-0.23	0.21	1.07	0.50	-0.01	-0.13	0.79	-0.42
41	*Artibeus jamaicensis*	0.09	0.22	0.65	0.47	1.22	0.47	0.47	0.24
42	*Artibeus jamaicensis*	-0.16	0.29	0.06	0.22	0.52	0.35	0.84	0.80
43	*Artibeus jamaicensis*	-0.17	0.31	1.51	-0.13	0.23	1.26	1.43	0.46
44	*Artibeus jamaicensis*	0.77	0.47	0.05	-0.13	0.05	-0.02	-3.04	0.33
45	*Artibeus jamaicensis*	-1.31	0.47	0.45	-0.07	0.59	0.48	0.73	-0.14
46	*Artibeus jamaicensis*	0.82	0.48	0.03	0.91	0.10	0.36	0.71	1.09
47	*Artibeus jamaicensis*	-0.23	0.53	0.95	-0.40	-0.05	-0.35	-0.36	-0.29
48	*Artibeus jamaicensis*	1.14	0.57	0.08	-0.06	0.24	1.25	0.75	2.57
49	*Artibeus jamaicensis*	-1.63	0.57	0.64	-0.64	-0.42	-0.15	0.21	0.24
50	*Artibeus jamaicensis*	-0.19	0.58	0.62	1.40	0.62	0.03	1.45	0.41
51	*Artibeus jamaicensis*	-0.26	0.58	1.19	0.21	-1.02	0.45	0.86	0.30
52	*Artibeus jamaicensis*	0.09	0.61	0.95	-0.71	0.63	0.51	0.27	0.24
53	*Artibeus jamaicensis*	1.18	0.61	-0.33	0.89	0.72	0.42	-0.45	0.24
54	*Artibeus jamaicensis*	-0.27	0.72	0.39	0.18	-0.43	0.92	0.26	0.52
55	*Artibeus jamaicensis*	0.65	0.77	0.02	0.59	0.50	0.50	0.23	-0.04
56	*Artibeus jamaicensis*	-0.19	0.85	1.20	-0.04	1.18	0.37	1.35	0.52
57	*Artibeus jamaicensis*	-0.19	0.89	1.45	0.44	0.62	0.42	0.66	0.71
58	*Artibeus jamaicensis*	1.10	0.90	0.55	0.84	0.51	0.44	0.19	0.62
59	*Artibeus jamaicensis*	-0.87	0.91	0.94	0.57	1.16	1.51	0.19	0.05
60	*Artibeus lituratus*	2.15	0.59	0.41	0.79	0.12	-0.02	-0.24	-0.04
61	*Artibeus lituratus*	-0.19	0.90	2.26	1.46	1.14	0.84	1.45	0.99
62	*Artibeus lituratus*	0.82	0.93	1.65	0.19	1.71	0.85	0.77	-0.14
63	*Artibeus lituratus*	0.07	0.95	0.88	0.54	-0.57	0.45	0.88	-0.14
64	*Artibeus lituratus*	0.09	1.20	0.29	0.26	0.21	0.43	0.67	0.24
65	*Artibeus lituratus*	-0.29	1.23	1.07	0.76	0.25	0.63	0.91	1.33
66	*Artibeus lituratus*	0.80	1.25	0.95	1.76	0.73	1.76	1.31	1.65
67	*Artibeus lituratus*	0.79	1.27	0.61	0.88	1.30	1.77	1.59	0.80
68	*Artibeus lituratus*	-1.69	1.28	1.93	0.75	0.69	1.72	-1.35	1.80
69	*Artibeus lituratus*	1.30	1.30	1.81	0.31	0.06	0.44	0.87	0.36
70	*Artibeus lituratus*	-0.29	1.37	0.34	0.85	0.65	0.50	0.15	0.43
71	*Artibeus lituratus*	1.09	1.37	0.06	-0.49	0.75	-0.11	1.13	0.30
72	*Artibeus lituratus*	2.81	1.46	0.89	2.35	1.91	2.07	1.73	2.69
73	*Artibeus lituratus*	1.11	1.53	0.95	1.46	0.20	0.40	0.86	1.75
74	*Artibeus lituratus*	0.90	1.53	1.47	1.47	1.68	1.20	1.35	0.76
75	*Artibeus lituratus*	2.07	1.55	1.07	2.06	2.12	1.73	-0.38	2.03
76	*Artibeus lituratus*	0.79	1.57	0.29	1.41	1.20	0.71	0.91	0.80
77	*Artibeus lituratus*	-0.07	1.62	2.03	0.84	1.14	1.71	0.98	1.93
78	*Artibeus lituratus*	0.16	1.68	1.73	1.76	0.71	1.00	1.45	1.47
79	*Artibeus lituratus*	0.75	1.92	0.85	1.75	0.52	0.38	1.34	1.49
80	*Artibeus lituratus*	-0.18	1.93	1.16	0.78	1.17	0.86	0.92	0.52
81	*Artibeus lituratus*	2.30	1.98	0.28	0.79	0.88	1.30	0.26	2.12

Ethical guidelines

Two individuals of *A. jamaicensis* (CZB–2019–11, CZB–2019–20) and one of *A. inopinatus* (CZB–2019–10) were sacrificed according to the guidelines for using mammals in wildlife research (Sikes et al. 2016) and preserved as fluid based on conventional methods (Rabinowitz et al. 2000; Kingston 2016). We collected the bats based on the researching and collection permit (Resolución–DE–MP–064–2017) issued by the Instituto Nacional de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre (ICF). All the specimens were deposited in the Zoological collection of the Pan-American Agronomical School (EAP is the abbreviation in Spanish).

Table 2. Coefficients of the linear discriminants. Abbreviations of the measurements are described in the section of Materials and methods.

Measurements	LD1	LD2
Ca	0.15287026	0.15481636
Fa	2.45027295	0.09891445
BL	-0.08092181	0.68550664
3mt	0.31353832	-0.11205364
1ph	-0.22273400	0.93985765
2ph	0.06936142	-1.51795449
3ph	0.10879933	-0.45551517
W	-0.23810171	0.31187190

Results

The 81 bats were captured in 42,485 m^2.h (0.002 individuals per m^2.h), and eight characteristics were analyzed in a total of 648 measurements. The classification rate was that 99% of individuals were assigned correctly. LD1 explained 99.57% of the discriminant analysis and LD2 the remaining 0.43% (Fig. 2). Based on LD1, the forearm (FA) and third metacarpal length (3mt) are the main characteristics for the external identification of *A. inopinatus*. Considering, LD2, the length of the second phalanx of digit III (1ph) and body length (BL) are the characteristics with the highest value. Based on the canonical classification of the external morphometrics measurements, the small-size group corresponds to *A. inopinatus*, the medium-size groups to *A. jamaicensis*, and the large-size groups to *A. lituratus* (Fig. 3). However, there is a slight overlap in size between *A. jamaicensis* and *A. lituratus*, and *A. inopinatus* (Fig. 4) and *A. jamaicensis* (see Table 3 for comparison of ANOVA analysis and Suppl. material 1 for specific measurements for each individual).

Discussion

Linear discriminant analysis has been used with other species of Phyllostomidae: for example Ruelas (2017) determined the main morphometric and skull characteristics of *Carollia* species in Peru, which were probably not well identified due to the use of controversial characteristics for their identification (this may be occurring for the species of *Carollia* in Honduras as well). Another example is Foltran Fialho (2009), who said that the main morphometric characteristic to identify *Artibeus* in Brazil is the forearm length, however, our results are more closely in accordance with Davis (1970), who indicated that forearm length is not a completely reliable indication for identifying all Central American members of *Artibeus* species.

Moreover, our results demonstrated a slight overlap between *A. inopinatus* and *A. jamaicensis* noted by Davis (1970), which occurs because the subspecies (e.g. *A. j. paulus*) of *A. jamaicensis* are smaller on the Pacific slope of Honduras near El Salvador in comparison to the subspecies (e.g. *A. j. yucatanicus* and *A. j. richardsoni*) that occur in the Atlantic slope that are relatively larger. This

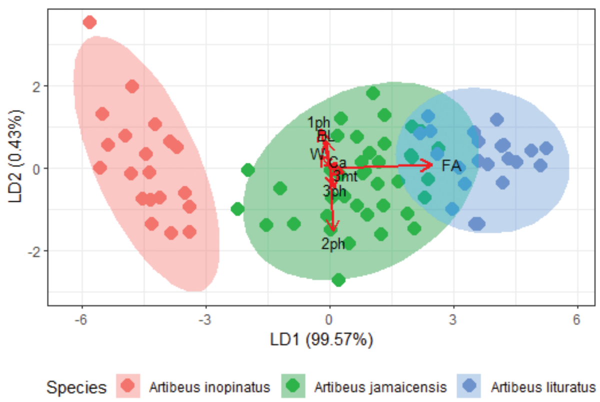

Figure 2. Linear Discriminant Analysis. LD1 just missed 0.43% to explain all the variance of the values of the morphometric measurements. Based on LD1 and LD2, the measurements with the highest value are the forearm length, third metacarpal length, the length of the second phalanx of digit III, and body length.

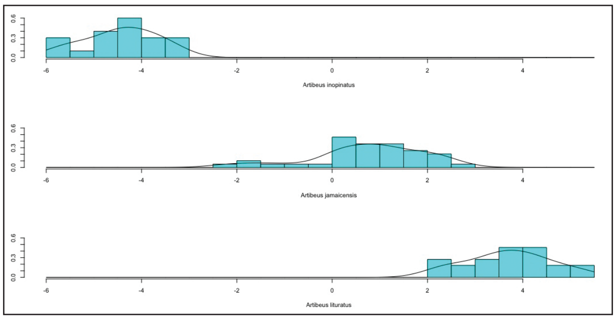

Figure 3. Column bars based on the frequency of the weights of the 648 morphometric measurements analyzed. Note a slight overlap between *A. jamaicensis* (second graph) and *A. inopinatus* (first graph), considered by Davis (1970), and an evident overlap between *A. jamaicensis* and *A. lituratus* (third graph).

Figure 4. Adult male of *Artibeus inopinatus* captured in Casco Urbano, Langue, Valle in southern Honduras. This was the smallest individual recorded in our study (all measurements in mm): Ca = 6.51, FA = 50.66, BL = 54.35, 3mt = 46.21, 1ph = 14.88, 2ph =23.19, 3ph = 15.95, and W = 25.90 g.

Table 3. ANOVA results of the eight studied characters of the three species of *Artibeus*. Note the comparison of the external measurements of *Artibeus inopinatus* of our records with those presented by Davis and Carter (1964).

	Artibeus inopinatus **(N = 20, this study)**	***Artibeus inopinatus*** **(N = 8, Davis and Carter [1964])**	***Artibeus jamaicensis*** **(N= 39, this study)**	***Artibeus lituratus*** **(N = 22, this study)**
Ca	5.69 (4.67–6.72)	–	7.02 (5.95–8.08)	7.77 (6.46–9.07)
FA	53.23 (52.11–53.34)	52.0 (51.7–52.3)	62.58 (60.26–64.91)	68.09 (66.49–68.09)
BH	63.72 (59.58–67.85)	–	70.96 (65.54–76.39)	76.77 (73.06–80.49)
3mt	48.57 (44.89–52.24)	46.4 (45.6–47.0)	57.39 (54.51–60.28)	61.96 (58.30–65.62)
1ph	16.26 (14.59–17.93)	14.8 (14.1–15.4)	19.77 (17.97–21.57)	21.92 (19.99–23.84)
2ph	26.07 (23.50–28.64)	24.0 (23.0–24.7)	32.21 (30.10–34.32)	34.80 (32.50–37.11)
3ph	18.63 (16.33–20.92)	12.6 (12.3–13.50)*	20.71 (18.61–22.81)	23.00 (21.00–25.00)
W	36.08 (30.35–41.81)	29.3 (24.7–35.9)	53.06 (46.18–59.95)	62.64 (53.97–71.32)

* They measured the 3ph without the cartilaginous tip.

overlap indicates that individuals of *A. jamaicensis* in southern Honduras might be confused with individuals of *A. inopinatus*. These features support that morphological differences between *Artibeus* may be a reflection of a combination of geographic and ecological constraints (Lim 1997). We strongly recommend complementing our work with measurements not included here from museum specimens to determine whether these variables are the most appropriate for field studies (e.g. probably some skull measurements might be more useful to discriminate *A. inopinatus* from *A. jamaicensis paulus*).

Differentiation based on cranium measurements was already analyzed in *Artibeus* (Lim 1997; Marchán-Rivadeneira et al. 2010), but were not specifically discussed considering *A. inopinatus*, and characteristics from the skulls can only be verified in dead specimens. Additionally, the results presented here indicate that the main characteristics for the external identification of *A. inopinatus* in the field in comparison with *A. jamaicensis* and *A. lituratus* are the forearm length, third metacarpal length, the length of the second phalanx of digit III, and body length. We agree with Lemos et al. (2020), that there are few measurements that for species determination, but linear morphometry alone is not sufficient to separate species. For example, *A. inopinatus*, even though it is the smallest of the *Artibeus* recorded in Honduras, relying on only one characteristic such as the forearm length might lead to the misidentification of the species, especially in southern Honduras. The controversial misidentification of *A. inopinatus* is related to a comment mentioned by Tate (1942) about students "relying upon others" observations and identifying "species" by morphological distinctions seen in a single type specimen. Our experience showed that many researchers in Honduras did not know about the occurrence of *A. inopinatus* because the taxonomic identification keys that they used before 2016 did not have characteristics for the identification of *A. inopinatus*.

Before Mora (2016) and Mora et al. (2018) there were no taxonomic identification keys for bats in Honduras, and most researchers used the keys of other countries, especially those of Mexico (Medellín et al. 2008) and Costa Rica (Timm et al. 1999), which do not include *A. inopinatus* because it is a species restricted to Honduras, El Salvador, and Nicaragua (Reid and Medina 2016). Given the controversial identification of *A. inopinatus* many researchers could have misidentified it in the field as other subspecies of *A. jamaincesis*, or even as juveniles of *A. jamaicensis* or *A. lituratus*. This could be one of the main reasons that *A. inopinatus* has been considered a rare species by Reid (2009), categorized with deficient data in the International Union for the Conservation of Nature (IUCN) by Reid and Medina (2016), or considered threatened in Honduras (Hernández 2015) due to the fragmentation and deforestation of the forests in the distributional area of *A. inopinatus.* However, in El Salvador is not considered neither threatened nor endangered (Girón and Rodríguez 2015), but in Nicaragua is considered endangered because there is a high impact due to the anthropogenic activities in the areas that the species is distributed along the country (Medina-Fitoria 2014; Medina and Saldaña 2015; Medina-Fitoria et al. 2017).

Recently, Portillo-Reyes et al. (2019) described presumably new records of *A. inopinatus* in Honduras, but they did not mentioned any criteria for the identification of *A. inopinatus* or collected any individual for the verification of the species, and this is why we considered that those individuals may be misidentified. From 1966 to 2001, there are 422 records of *A. inopinatus* for Honduras in the database of GBIF.org (2019) (not 454 as erroneously mentioned by Portillo-Reyes et al. [2019], there are 422 records for Honduras, 21 in El Salvador, and 11 in Nicaragua). The records in the GBIF.org (2019) database indicate that *A. inopinatus* may not be rare in several areas of Honduras; however, not much sampling effort has been done in Honduras since 2001. But based in our records, *A. inopinatus* is not rare, at least in southern Francisco Morazán – for example in a survey during August 2018 in Sabanagrande, 65% of all the captures of that night were of *A. inopinatus*. Based on historical records and this study, Sabanagrande in southern Francisco Morazán may represent the most important area in Honduras for the conservation of *A. inopinatus* in the country.

A. inopinatus was previously recorded only in the departments of Valle, Choluteca, Francisco Morazán, and El Paraíso (GBIF.org 2019). Now the distribution of the species is extended to Comayagua, and the elevational range to 1435 m in the locality of Villa Las Marías in San Buenaventura, Francisco Morazán (before it was known to occur in areas up to 1100 m [Reid and Medina 2016]). Initially, *A. inopinatus* was recorded in dry thorn scrubs, deciduous forests, banana groves and abandoned houses (Baker and Jones 1975; Dolan and Carter 1979; Webster and Jones 1983; Reid 2009) or near bodies of water (Davis and Carter 1964). However, the habitats of the species now include areas above bodies of water or dry pathways of water, under fig trees (*Ficus*: Moraceae) and mango trees (*Mangifera*: Anacardiaceae), and in pine forests where *Pinus oocarpa* and *P. maximinoi* are abundant. From February 2015 to September 2019, between 18:10 h and 03:25 h we captured individuals of *A. inopinatus* with following species: *Phyllostomus discolor*, *Lonchorhina aurita*, *Micronycteris microtis*, *Artibeus jamaicensis*, *A. lituratus*, *Carollia perspicillata*, *C. subrufa*, *C. castanea*, *C. sowelli*, *Dermanura phaeotis*, *D. watsoni*, *D. tolteca*, *Chiroderma salvini*, *C. villosum*, *Diphylla ecaudata*, *Desmodus rotundus*, *Centurio senex*, *Glossophaga soricina*, *Choeroniscus godmani*, *Enchisthenes hartii*, *Sturnira parvidens*, *S. hondurensis*, *Platyrrhinus helleri*, *Mormoops megalophylla*, *Pteronotus fulvus*, *P. gymnonotus*, *P. mesoamericanus*, *Eptesicus furinalis*, *E. fuscus*, *Rhogeessa bickhami* and *Molossus alvarezi*. Previously, *A. inopinatus* was captured only with *Balantiopteryx plicata* and *Myotis albescens* (Webster and Jones 1983).

In conclusion, the characteristics that may be helpful in the external identification of *A. inopinatus* during fieldworks are the forearm length and third metacarpal length, in conjunction with the length of the second phalanx of digit III and body length. Nevertheless, we must complement our identification with other features, such as the fringe of the uropatagium, and geographical distributions (*A. inopinatus* has been only recorded only in Comayagua, Francisco Morazán, El Paraíso, Valle, and Choluteca). Finally, we strongly recommend using statistical analysis in the elaboration of keys for taxonomic identification with a differentiation among specimens of museum and live specimens and, whenever possible, a distinction among young and adults, and females and males, as well as subspecies. A combination of genetic analyses, skull measurements, higher sampling effort, and populational studies is needed to determine the conservational status of *A. inopinatus*, and to clarify the systematics among *A. lituratus*, *A. inopinatus*, and subspecies of *A. jamaicensis*.

Acknowledgments

We are grateful to Sabrina Amador of the Smithsonian Tropical Research Institute (STRI) for all the knowledge transmitted and collaboration given during this research; to the Zoological collection of the Pan-American Agronomical School for receiving the specimens to their collection. To Jean Kollantai of Tomsk State University for language proofreading. We are very thankful to the Colección Privada y Centro de Rescate de Fauna Silvestre “El Ocotal”, especially to the family of Alejandro Velásquez and the community of Sabanagrande in Francisco Morazán, for their support during all the research. We are grateful to Mario Reyes, Gustavo Barahona, Olmán Álvarez, and Brenda Álvarez for their kindness and collaboration during the surveys in Francisco Morazán; to Nereyda Estrada, Erick Tercero and Sur en Acción for their collaboration in Choluteca; to ASIDE, UNACIFOR, Región Forestal of Comayagua of the ICF, and Javier Zúniga for their collaboration during the surveys in Comayagua; to Franklin Castañeda, Travis King and Kevin Rivera for their collaboration in Atlántida; to Marcío Martínez and Región Forestal Biosfera Río Platano of the ICF for their collaboration in the surveys in Gracias a Dios; and to the cordial family of Hefer Ávila and the community of Langue for their collaboration in the surveys in Valle. Finally, to Alexander Haas, Sergio Solari, Felipe Pessoa da Silva, Simon Ripperger and two anonymous reviewers for improving this manuscript.

References

Ávila-Palma HD, Turcios-Casco MA, Ordoñez Bautista DJ, Martínez M, Ordoñez-Mazier DI (2019) First records of *Mimon cozumelae* Goldman, 1914 (Chiroptera, Phyllostomidae) in the Río Plátano Biosphere Reserve in northeastern Honduras. Check List 15(6): 1113–1118. https://doi.org/10.15560/15.6.1113

Baker RJ, Jones Jr JK (1975) Additional record of bats from Nicaragua, with a revised checklist of the Chiroptera. Occasional Papers The Museum Texas Tech University 32: 1–13. https://doi.org/10.5962/bhl.title.142873

Brunet-Rossinni AK, Wilkinson GS (2009) Methods for age estimation and the study of senescence in bats. In: Kunz TH, Parsons S (Eds) Ecological and behavioral methods for the study of bats. The John Hopkins University Press, Baltimore, 315–325.

Cirranello A, Simmons NB, Solari S, Baker RJ (2016) Morphological diagnoses of higher-level phyllostomid taxa (Chiroptera: Phyllostomidae). Acta Chiropterologica 18(1): 39–71. https://doi.org/10.3161/15081109ACC2016.18.1.002

Davis WB (1970) The large fruit bats (Genus *Artibeus*) of Middle America, with a review of the *Artibeus jamaicensis* complex. Journal of Mammalogy 51(1): 105–122. https://doi.org/10.2307/1378537

Davis WB (1984) Review of the large fruit-eating bats of the *Artibeus* “*lituratus*” complex (Chiroptera: Phyllostomidae) in Middle America. Occasional Papers The Museum Texas Tech University 93: 1–16. https://doi.org/10.5962/bhl.title.156552

Davis WB, Carter DC (1964) A new species of fruit-eating bat (genus *Artibeus*) from Central America. Proceedings of the Biological Society of Washington 77: 119–122. https://www.biodiversitylibrary.org/page/34605354

Dolan PG, Carter DC (1979) Distributional notes and records for Middle American Chiroptera. Journal of Mammalogy 60(3): 644–649. https://doi.org/10.2307/1380115

Foltran Fialho FS (2009) Análise morfométrica, morfológica e citogenética de morcegos do gênero *Artibeus* Leach, 1821 (Chiroptera, Phyllostomidae) (Master thesis). BrasUniversidade de Brasília, Brasília

GBIF.org [Global Biodiversity Information Facility] (2019) GBIF Occurrence. https://www.gbif.org/occurrence/search [accessed 02 September 2019].

Girón L, Rodríguez M (2015) Programa para la conservación de los murciélagos de El Salvador (PCMES). In: Rodríguez Herrera B. Sánchez R (Eds) Estrategia centroamericana para la conservación de los murciélagos. Universidad de Costa Rica, San José, 23–30.

Hernández DJ (2015) Programa para la conservación de los murciélagos de Honduras (PCMH). In: Rodríguez Herrera B, Sánchez R (Eds) Estrategia centroamericana para la conservación de los murciélagos. Universidad de Costa Rica, San José, 41–55.

Hoofer SR, Solari S, Larsen PA, Bradley RD, Baker RJ (2008) Phylogenetics of the fruit-eating bats (Phyllostomidae: Artibeina) inferred from mitochondrial DNA sequences. Occasional Papers The Museum Texas Tech University 277: 1–15. https://doi.org/10.5962/bhl.title.156929

Holdridge LR (1967) Life zone ecology. Tropical Science Center, San José, 206 pp.

Kingston T (2016) Bats. In: Larsen T (Ed.) Core standardized methods for rapid biological field assessment. Conservation International, Virginia, 59–82.

Kunz TH, Kurta A (1988) Capture methods and holding devices. In: Kunz T (Ed.) Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington DC, 1–28.

Larsen PA, Hoofer SR, Bozeman MC, Pedersen SC, Genoways HH, Phillips CJ, Pumo DE, Baker RJ (2007) Phylogenetics and phylogeography of the *Artibeus jamaicensis* complex based on cytochrome-b DNA sequences. Journal of Mammalogy 88(3): 712–727. https://doi.org/10.1644/06-MAMM-A-125R.1

Larsen PA, Marchán-Rivadeneira M, Baker RJ (2010) Taxonomic status of Andersen's fruit-eating bat (*Artibeus jamaicensis aequatorialis*) and revised classification of *Artibeus* (Chiroptera: Phyllostomidae). Zootaxa 2648: 45–60. https://doi.org/10.11646/zootaxa.2648.1.3

Lim BK (1997) Morphometric differentiation and species status of allopatric fruit-eating bats *Artibeus jamaicensis* and *A. planirostris* in Venezuela. Studies on Neotropical Fauna and Environment 32(2): 94–100. https://doi.org/10.1080/01650521.1997.9709606

Lemos TH, da Cunha Tavares V, Moras LM (2020) Character variation and taxonomy of short-tailed fruit bats from *Carollia* in Brazil. Zoologia 37: 1–7. https://doi.org/10.3897/zoologia.37.e34587

Marchán-Rivadeneira MR, Phillips CJ, Strauss RE, Guerrero JA, Mancina CA, Baker RJ (2010) Cranial differentiation of fruit-eating bats (genus *Artibeus*) on size-standardized data. Acta Chiropterologica 12(1): 143–154. https://doi.org/10.3161/150811010X504644

Medellín RA, Arita HT, Sánchez HO (2008) Identificación de los murciélagos de México, clave de campo. Universidad Nacional Autónoma de México, Distrito Federal, 83 pp.

Medina A, Saldaña O (2015) Programa para la conservación de los murciélagos de Nicaragua (PCMN). In: Rodríguez Herrera B, Sánchez R (Eds) Estrategia centroamericana para la conservación de los murciélagos. Universidad de Costa Rica, San José, 57–68.

Medina-Fitoria A (2014) Murciélagos de Nicaragua, guía de campo. Ministerio del Ambiente y los Recursos Naturales (MARENA), Managua, 278 pp.

Medina-Fitoria A, Saldaña O, Aguirre Y, Salazar M, Martínez JG (2017) Lista roja de los murciélagos de Nicaragua y su estado de conservación. Boletín de la Red Latinoamericana y del Caribe para la Conservación de los Murciélagos 8(2): 12–20. https://relcomlatinoamerica.net/images/PDFs/Boletines/2017-8-2_May-Ago.pdf

Mora JM (2016) Clave para la identificación de las especies de murciélagos de Honduras. Ceiba 54 (2): 93–117. https://doi.org/10.5377/ceiba.v54i2.3283

Mora JM, López LI, Espinal M, Marineros L, Ruedas L (2018) Diversidad y conservación de los murciélagos de Honduras. Master Print S. de R.L., Tegucigalpa, 300 pp.

Owen RD (1991) The systematic status of *Dermanura concolor* (Peters, 1865) (Chiroptera: Phyllostomidae), with description of a new genus. Bulletin American Museum of Natural History 206; 18–25.

Portillo-Reyes HO, Aguirre Y, Hernández J (2019) Registro de una población del murciélago frutero hondureño (*Artibeus inopinatus*), en Nacaome, Valle, Honduras. Scientia hondurensis 2(1): 71–75.

Rabinowitz A, Hart J, White L (2000) Information from dead animals and their curation. In: White L, Edwards A (Eds) Conservation research in the African rain forests: *a technical handbook*. Wildlife Conservation Society, New York, 185–195.

R Core Team (2015) R: A language and Environment for statistical computing. https://www.R-project.org/

Redondo RAF, Brina LPS, Silva RF, Ditchfield AD, Santos FR (2008) Molecular systematics of the genus *Artibeus* (Chiroptera: Phyllostomidae). Molecular Phylogenetics and Evolution 49: 44–58. https://doi.org/10.1016/j.ympev.2008.07.001

Reid F (2009) A field guide to the mammals of Central America & southeast Mexico. Second edition. Oxford University Press, New York, 346 pp.

Reid F, Medina A (2016) *Artibeus inopinatus*. The IUCN Red List of Threatened Species 2016: e.T2132A21996586.

Ruelas D (2017) Diferenciación morfológica de *Carollia brevicauda* y *C. perspicillata* (Chiroptera: Phyllostimdae) de Perú y Ecuador. Revista Peruana De Biología 24(4): 363–382. https://doi.org/10.15381/rpb.v24i4.14063

Sikes RS, The Animal Care and Use Committee of the American Society of Mammalogists (2016) Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. Journal of Mammalogy 97(3): 663–688. https://doi.org/10.1093/jmammal/gyw078

Simmons NB, Voss RS (1998) The mammals of Paracou, French Guiana: a Neotropical lowland rainforest fauna, part 1, bats. Bulletin of the American Museum of Natural History 237: 1–219. https://digitallibrary.amnh.org/handle/2246/1634

Srinivasulu C, Racey PA, Mistry S (2010) A key to the bats (Mammalia: Chiroptera) of South Asia. Journal of Threatened Taxa 2(7): 1001–1076. https://doi.org/10.11609/JoTT.o2352.1001-76

Straube FC, Bianconi GV (2002) Sobre a grandeza e a unidade utilizada para estimar esforço de captura com utilização de redes-de-neblina. Chiroptera Neotropical 8(1–2): 150–152.

Tate GHH (1942) Review of the Vespertilionine bats, with special attention to genera and species of the Archbold collections. Bulletin of the American Museum of Natural History 80(7): 221–297. http://hdl.handle.net/2246/1783

Timm RM, LaVal RK, Rodríguez-H B (1999) Clave de campo para los murciélagos de Costa Rica. Brenesia 52: 1–32.

Turcios-Casco MA, Medina-Fitoria A, Estrada-Andino N (2020) Northernmost record of *Chiroderma trinitatum* (Chiroptera, Phyllostomidae) in Latin America, with distributional comments. Caribbean Journal of Science 50(1): 9–15. https://doi.org/10.18475/cjos.v50i1.a2

Velazco PM, Cadenillas R (2011) On the identity of *Lophostoma silvicolum occidentalis* (Davis and Carter, 1978) (Chiroptera: Phyllostomidae). Zootaxa 2962: 1–20. https://doi.org/10.11646/zootaxa.2962.1.1

Webster D, Jones Jr K (1983) *Artibeus hirsutus* and *Artibeus inopinatus*. Mammalian species 199: 1–3. https://doi.org/10.2307/3503811

Wilson DE, Mittermeier RA (2019) Handbook of the mammals of the world. Lynx Ediciones, Barcelona, 1008 pp.

Supplementary material 1

Morphometric data of 81 *Artibeus* in Honduras

Authors: Manfredo Alejandro Turcios-Casco, Hefer Daniel Ávila-Palma, Eduardo Javier Ordoñez Trejo, José Alejandro Soler Orellana, Diego Iván Ordoñez Mazier, David Eduardo Meza-Flores, Alejandro Velásquez

Data type: Morphometric dataset with coordinates of its occurrence.

Explanation note: Morphometric data of each recorded individual (all the measurements are in millimeters, and the weight in grams), coordinates (Geographical), elevation (meters above sea level), departments, municipalities, main localities, and life zones based on Holdridge (1967) in which they were recorded. Abbreviations: BJKFNP (Blanca Jeannette Kawas Fernández National Park), CSWR (Cuero y Salado Wildlife Refuge), CU-UNAH (Ciudad Universitaria, Universidad Nacional Autónoma de Honduras), LBG (Lancetilla Botanical Garden).

Link: https://doi.org/10.3897/evolsyst.4.49377.suppl1