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A dietary analysis of *Phyllostomus discolor* with potential evidence of mammal predation

Un análisis dietético en *Phyllostomus discolor* con evidencia potencial de depredación en mamíferos

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Phyllostomus discolor is considered an omnivore, with a high consumption of nectar. The consumption of vertebrates has never been documented in *P. discolor*. However, there is a documented attack on *Eptesicus furinalis*, and frog remains were found under a colony of this bat. We obtained a fecal sample from *P. discolor*, which contained a potential record of mammal predation. The main objective of this study was to compare this sample with the anatomy of some small mammals occurring in the Chocó, as well as report other findings from this sample. We contrasted a part of the sample with photographs of bats and rodents' claws. We applied a PCA analysis to compare this part of the sample with bat and rodent claw sizes. We used field guides and literature to identify insects, seeds, and minerals. The sample contained insects, gravel, one seed, hair spines, and a claw. The spines found were morphologically more related to the spines identified in *Neacomys marci* in comparison to *Heteromys australis*. Although the claw shape-size was similar to *N. marci*, some bats had a similar appearance, and the differences were small. This note would represent the first potential record of *P. discolor* hunting a mammal in natural conditions, but we recommend further analyses and comparisons on its dietary composition.

Key words: Hair structure; nail anatomy; Phyllostominae; spiny mouse; vertebrate consumption.

Phyllostomus discolor es considerado omnívoro, con un alto consumo de néctar. Nunca se ha documentado el consumo de vertebrados en *P. discolor*. Sin embargo, hay un ataque documentado a *Eptesicus furinalis* y se encontraron restos de rana debajo de una colonia de esta especie. Obtuvimos una muestra fecal de *P. discolor*, que contenía un registro potencial de depredación en mamíferos. El principal objetivo de este estudio fue comparar esta muestra con la anatomía de algunos pequeños mamíferos presentes en el Chocó, así como reportar otros hallazgos de esta muestra. Se contrastó una parte de la muestra con fotografías de garras de murciélagos y roedores. Aplicamos un análisis PCA para comparar esta parte de la muestra con el tamaño de las garras de murciélagos y roedores. Usamos guías de campo y literatura para identificar insectos, semillas y minerales. La muestra contenía insectos, grava, una semilla, espinas y una garra. Las espinas encontradas estaban morfológicamente más relacionadas con las espinas identificadas en *Neacomys marci* en comparación con *Heteromys australis*. Aunque la forma y el tamaño de la garra eran similares a los de *N. marci*, algunos murciélagos tenían una apariencia similar y las diferencias eran pequeñas. Esta nota representaría el primer registro potencial de *P. discolor* cazando un mamífero en condiciones naturales, pero recomendamos análisis y comparaciones adicionales sobre su composición dietética.

Palabras clave: Anatomía de las uñas; consumo de vertebrados; estructura del pelo; Phyllostominae; ratón espinoso.

In general, *Phyllostomus discolor* is considered an omnivore bat, but is primarily a nectarivore with a low consumption of insects (Giannini and Kalko 2005; Quinche *et al.* 2023). Many studies show that diet composition in *P. discolor* is highly diverse as well as variable according to the seasonality of the ecosystem; there are dietary records of nectar, pollen, fruits, and flower's parts, but also of insects like Coleoptera, Diptera, Hymenoptera, and Lepidoptera (Kwiecinski 2006; Quinche *et al.* 2023). The consumption of vertebrates in *P. discolor* has never been analyzed formally, and scientific literature has suggested this bat might feed on frogs (Kwiecinski 2006). Uieda and Hayashi (1996) reported the remains of the leg of frog *Leptodactylus latrans*, formerly *L. ocellatus*, under the roost of a colony of *P. discolor,* suggesting the consumption of small vertebrates. The remains were obtained on the floor of a church tower named Catedral da Sé, located in the urban area of Crato, in the State of Ceará, northeastern Brazil. The authors did not provide additional analyses or comparisons for this finding but suggested that *P. discolor* could recognize a living prey on the ground and carry it to their roost. Posterior dietary analyses and revisions show that *P. discolor* does not feed on vertebrates (Giannini and Kalko 2005; Hemingway *et al.* 2020). Guevara *et al.* (2022) recorded an attempted predation of *P. discolor* on *Eptesicus furinalis* (Vespertilionidae), in the Mamoní valley, near San José Commnunity, Chepo Distrite, Panamá. They observed a male *Phyllostomus discolor* flying to a mist net, and biting a recently captured specimen of *E. furinalis*. Because this specimen was entangled to the mist net, *P. discolor* released it and desisted of this catching. Immediately, it flew 2 m far away of the injured bat and was captured in the same mist net. The photographic material provided by the authors showed severe injuries on the right wing and shoulder of *E. furinalis*. The authors considered this behavior as an opportunistic event of predation by *P. discolor*. This record represents an attack in unnatural conditions, and does not probe predation by itself, because there is no tangible evidence of bat/meat consumption. However, there are additional details in the literature that suggest the presence of carnivore behavior in this bat. In conditions of captivity, *P. discolor* can assimilate small portions of meat into its diet, McNab (1969) stated that this bat requires a small, but regular, intake of meat. The author mentioned providing it with fruit, fish, and meat in captivity without mentioning specifically what type of animal meat. To understand how possible it is for *P. discolor* to hunt vertebrates and digest meat, a brief review of its adaptations related to its feeding habits is necessary.

Morphologically, *P. discolor* has a relatively long, protrusible tongue with small papillae, a long, and narrow snout/palate, and a narrow and shallow palatal groove; however, its general appearance does not resemble the highly specialized morphology of other nectarivores such as Glossophaginae and Lonchophyllinae (Quinche *et al.* 2023). Those bats have a delicate, and elongated snout/palate with small teeth; their tongues and papillae are longer, and they have a wide and deep palatal groove (Quinche *et al.* 2023). The skull *in P. discolor* is robust, it has a low and broad rostrum, a rounded braincase, and bigger teeth (Kwiecinski 2006). The presence of dilambdodont expanded dentition and uropatagium is more related with the consumption of insects and other vertebrates, such as those observed in other related omnivorous bats (Kwiecinski 2006; Duque Osorio *et al.* 2011).

Biomechanically, *P. discolor* has a considerable bite strength, that is 21.61 Newtons (Aguirre *et al.* 2003). This strength can be explained by the presence of a robust zygomatic arch, a great extension of the interparietal region, a high coronoid process, and an expanded angular process; which provide a large area for the attachment of masticatory muscles (Nogueira *et al.* 2009; Quinche *et al.* 2023). The opposite is true for highly specialized nectarivores, some species lack zygomatic arches (*i.e., Anoura geoffroyi*; Dumont 2004). Behaviorally, *P. discolor* is a gleaning nectarivore, it shows an intermediate foraging behavior between omnivorous phyllostomids, which use a prolonged landing, and specialized nectarivorous, which use hovering (Quinche *et al.* 2023). This bat forages in highly cluttered spaces and feeds on large flowers of trees, shrubs, or vines, and it is constantly performing brief landings and take-offs on flowers (Kalko *et al.* 1996; Quinche *et al.* 2023). The foraging behavior of this bat would be useful to catch small prey. Physiologically, *P. discolor* still maintaining the production of aminopeptidase-N, an intestinal enzyme useful to cleave and digest proteins and peptides present in meat; it has a high relative medullary thickness (RMT) in the kidney; and it exhibits a high urine-concentrating capacity. In phyllosttomids, a high RMT, together with the production of concentrated urine, and a high enzymatic activity of aminopeptidase-N have been associated with carnivorous, insectivores, and hematophagous feeding habits. Frugivores and nectarivores have lower RMTs and less concentrated urine (Schondube *et al.* 2001).

The generalist traits and highly diverse dietary habits observed in *P. discolor* have been suggested to create tradeoffs against the morphological specialization of the skull, palate, and tongue towards nectarivory (Quinche *et al.* 2023). Hypothetically, the adaptations of *P. discolor* would not be an impediment for this species to feed on smaller vertebrates and digest meat, but this behavior must be infrequent given the known state of the art of the species (Giannini and Kaljo 2005). We obtained a fecal sample from a specimen of *P. discolor*, which contained potential records of mammal predation. Thus, the main objective of this study was to compare these findings with the claws and hair spine anatomy of some rodents and bats occurring in the Ecuadorian Andean Chocó, as well as report other findings of this sample.

We obtained our samples in the Mashpi Shungo Reserve, in the northwestern part of Pichincha Province, Ecuador (0° 10' 56.92 "N, 78° 54' 44.28" W, 516 m). The habitat corresponds to an evergreen lowland forest of the western Andes Mountain range (MAE 2013). The weather in the region is subtropical, with a mountainous topography, and it is considered an unexplored area due to its difficult access. This area is also very important in terms of biodiversity because it belongs to the Andean Chocó Biosphere Reserve, one of the most biodiverse ecosystems in the world (Pérez-Escobar *et al.* 2019).

From July 29 to August 6, 2021, at the Mashpi Shungo Reserve, we placed 7 mist nets of variable sizes: 6, 9, 10, and 12 m, during 9 sampling nights, at an elevation ranging from 500-600 m in several habitats including primary forests, secondary forests, pastures for cattle, banana and cacao crops, and near to a small river. We captured 81 bats, including a specimen of *P. discolor* (MECN 7430, Museo Ecuatoriano de Ciencias Naturales), which was captured by the river. We kept this specimen inside a cloth bag for 1 hr, aiming to obtain fecal samples. Due to high accelerated metabolism of bats, their digestion occurs from 30 min to 1 hr after feeding (Saldaña-Vázquez 2014; Arias and Pacheco 2019). We cleaned cloth bags after each capture to prevent sample contamination. We obtained 1 fecal sample, that we labeled with the same field number as our voucher. We preserved this sample in a 2 ml Eppendorf tube with 70 % ethanol.

We meticulously separated fecal remains with the use of entomological tweezers in a tray. We used a stereo microscope and several field guides to identify a part of the dietary items, especially seeds and insects, at the lowest taxonomic level (Borror and White 1970; Kirkbride *et al.* 2006; Lobova and Mori 2007). Another part of this sample was compared with the anatomical structures of museum specimens of rodents and bats co-occurring in the Ecuadorian Andean Chocó. We reviewed the mammal collection of the Instituto Nacional de Biodiversidad, formerly Museo Ecuatoriano de Ciencias Naturales (MECN), and the Museo de la Escuela Politécnica Nacional (MEPN). Thus, the sample was compared with hair spines and claws of *Neacomys marci*, and *Heteromys australis*. We also compared it with the claws of small bat species: *Thyroptera tricolor*, *Myotis oxyotus*, *Myotis riparius*, *Vampyressa thyone*, *Micronycteris megalotis*, *Rhinophylla alethina*; and medium-size bat, *Sturnira ludovici*; details of voucher specimens are provided in Appendix 1. Apart from *Peropteryx pallidoptera*, all of the bats included in this study have previously been documented in the Andean Chocó (Tirira 2017; Rodríguez-Segovia and Gavilánez-Endara 2023).

We did not use other types of small bats like *Furipterus horrens*, *Rhogeessa* spp., *Neoeptesicus* spp., and *Carollia* spp., because we assumed they had developed similar claw anatomy and shape in comparison to selected species due to convergent evolution (Tsagkogeorga *et al.* 2013). We only used adult specimens for our analysis. For bats, age was determined by seeing the fused degree of hand-wing epiphyses (Rodríguez-Segovia 2022); and for rodents, age was determined based on molar eruption and wear (Sobral and Oliveira 2014). For the rodents analyzed, we obtained 3 random dorsal hair samples from each specimen with the help of a hair tweezer.

We photographed these samples under the stereo microscope, and we classified them according to their width and shape. We principally photographed and compared the claws of the right foot of each bat analyzed, and the nails of the right hand of each rodent analyzed. When comparing the anatomy of rodent and bat claws with our sample, we consider most of its structure to be complete, from tips to insertion to the phalanx. There were small cracks, but only a unique broken piece. Considering this, we used a digital caliper to measure the length, height, and width, of each claw, from fingers II – V (Cricetids have rudimentary thumbs with no claw), in the right hand of *Heteromys australis* (MECN 7559, *n* = 4) and *Neacomys marci* (MECN 6766, *n* = 4). We proceeded in a similar way in fingers I – V. At the right foot of each species of bat, *Thyroptera tricolor* (*n* = 5), *Myotis oxyotus* (*n* = 5), *Myotis riparius* (*n* = 5), *Vampyressa thyone* (*n* = 5), *Micronycteris megalotis* (*n* = 5), *Rhinophylla alethina* (*n* = 5), and *Sturnira ludovici* (*n* = 5). The sample obtained from the fecal remains was measured the same way, and we then compared it to the rodents and bats analyzed (Figure 1). We performed a Principal Component Analysis (PCA) in the R package Vegan and the RStudio program to explore how related the samples were in size (Oksanen *et al.* 2020; RStudio Team 2020). Additionally, we reviewed specialized literature to identify the anatomical structures present in rodent and bat claws (Fleckman *et al.* 2013; Pulawska-Czub *et al.* 2021).

Another part of the sample contained blackish materials that were carefully reviewed under the microscope. We performed a dissection on part of these materials with the help of a scalpel and dissecting needle. We finally compare these materials with the literature regarding the anatomical structures of plant seeds (Leubner 2000).

Our samples were collected according to the guidelines from The American Society of Mammologist (Sikes and Gannon 2016). Permit for this research (MAAE-

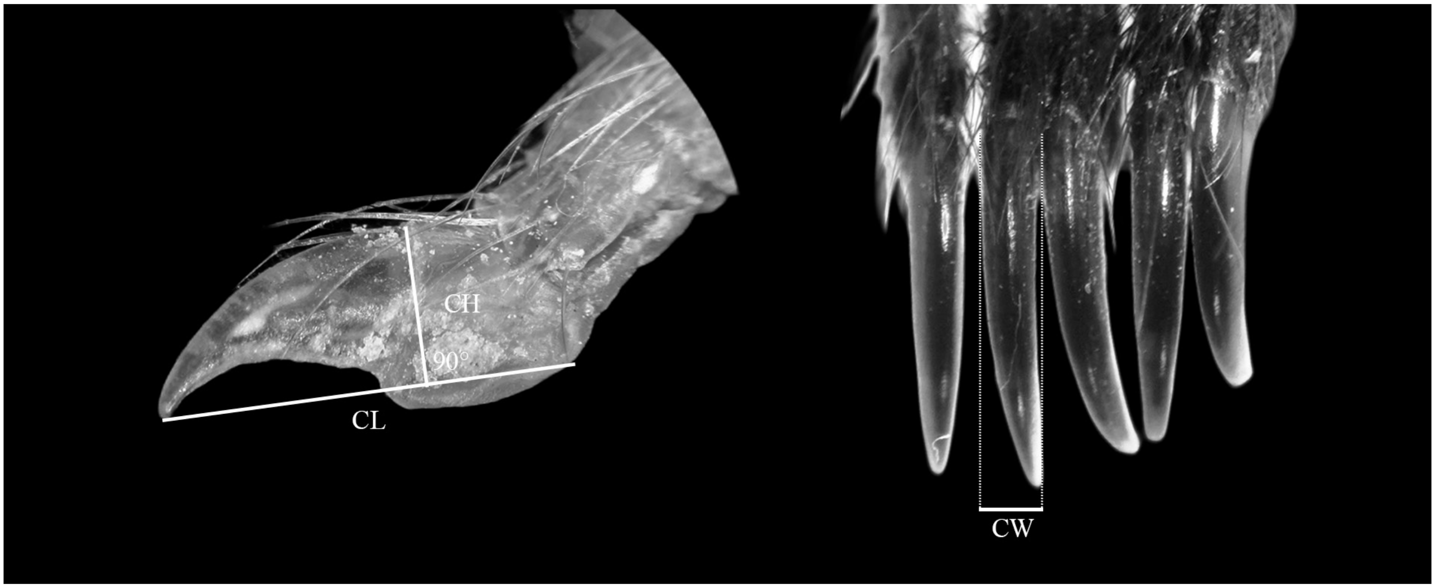

Figure 1. Measurements taken. Claw Length (CL): a distance from claw tip to the most posterior border of claw base, near the end of food pad Claw Height (CH): a 90° perpendicular line drawn over Claw Length, but which connect the higher point of the claw, Claw Width (CW): claw width at the lunula.

ARSFC-2021-1644) was granted by the Ministerio del Ambiente Agua y Transición Ecológica del Ecuador, all the associated material was deposited in the Museo Ecuatoriano de Ciencias Naturales (MECN).

Among the sample contains, there were 3 findings with difficult taxonomic assignment: a claw, hair spines and several blackish materials. We found 2 hair spines in the fecal sample. Part of their structure was damaged, probably by the process of digestion. The spines had a brownish appearance with some orange portions. A longitudinal sulcus on the dorsal surface of the hair spines was observed, which was present from the base to the tip of the hair (Figure 2a, b). The hair spines were compared with the hair spines of *N. marci*, a mouse with brown to orange-brown fur and at least 3 different types of dorsal hair spines of similar colors (Figure 2c), type I and type II have a thinner appearance, and type I is different from type II due to a terminal portion that is expanded, and a little bit rounded (Figure 2d; zoom type I - II). Type III has a wide appearance (Figure 2d, zoom type III). Hair spines in this species, only have a longitudinal sulcus on their dorsal surface, this structure is present from the base to the tips (Figure 2a - d). *Heteromys australis* has gray to blackish fur, with somewhat paler dorsal hair spines that give it a frosty appearance (Figure 2e). We consider a unique type of hair spines in this rodent, which has a wide dorsal and a short ventral longitudinal sulcus, with tips pointer than those observed in *N. marci,* the sulcus ends before the tips of each spine (Figure 2f).

The anatomical parts and the shape of the base of the claw examined were more related to those observed in *N. marci* and *H. australis*, rather than bats. The claws of small rodents reviewed have a shiny, whitish appearance, are somewhat translucent, and are concave on their ventral side. They show growth lines due to the accumulation of keratin and at the base, it is possible to differentiate the lunula, cuticle and proximal nail fold (Figure 2g - i). In general, the claws of the bats analyzed are more curved, longer, and thicker (except in *T. tricolor*; Figure 2j - q). The claws of *R. alethina*, *S. ludovici*, and *M. oxyotus* are darkness in color when compared with other species of bats (Figure 2 j, k, o). In *V. thyone*, *M. megalotis*, *M. riparius* and *T. tricolor* claws have a paler color, like that of rodents (Figure 2l – n, q). There are dense ungunal hairs in *R. alethina*, *S. ludovici*, *V. thyone*, and *M. megalotis* (Figure 2j - m). There are sparse ungunal hairs in *N. marci*, *H. australis, M. riparius*, and *M. oxyotus* (Figure 2h, i, n, o). Fingers are mostly

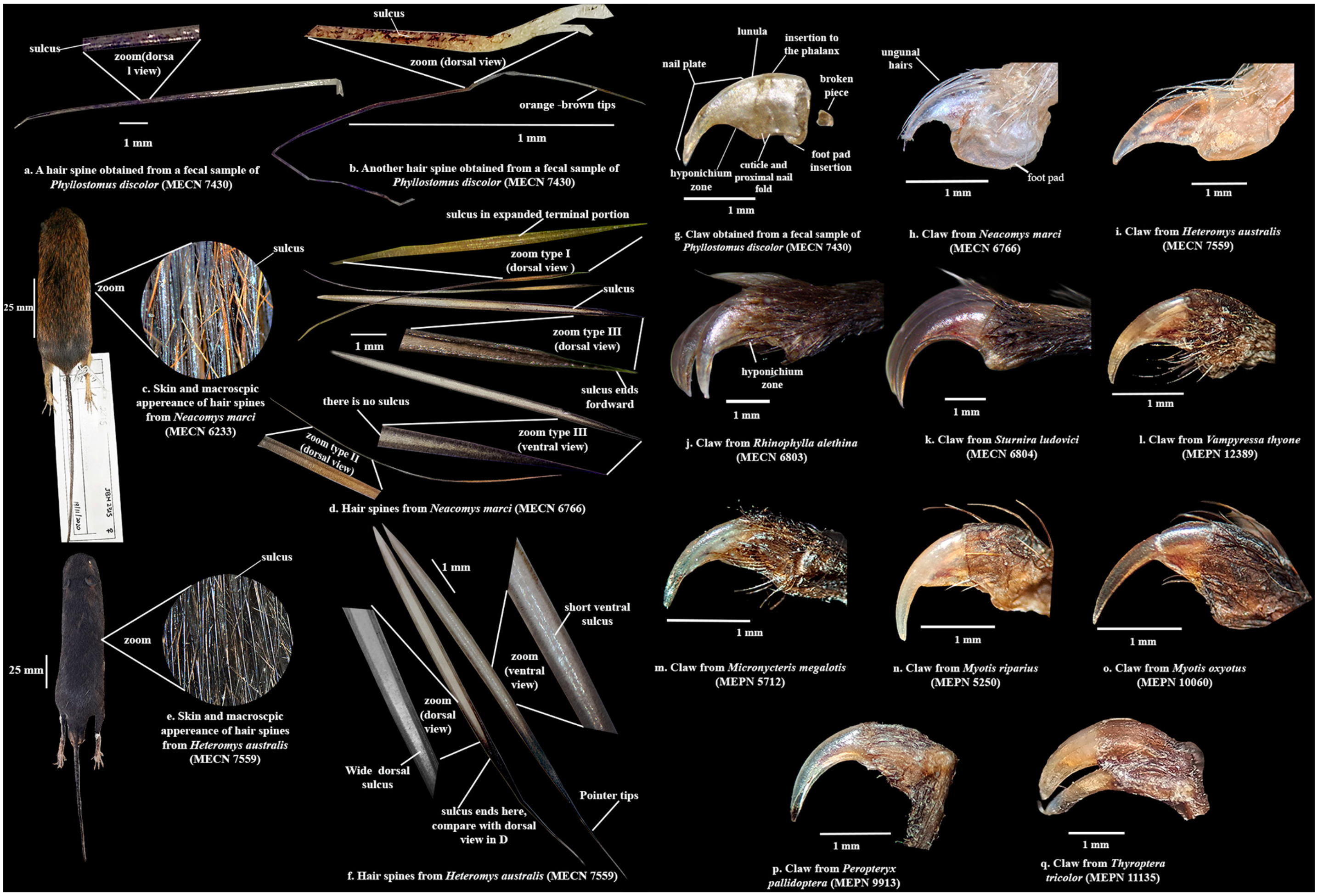

Figure 2. Hair spines and claws analyzed**.** Skin comparisons of hair spines of species distributed in the study area are shown in the left side. A close up shows the longitudinal dorsal sulcus present in *Neacomys marci*, and a close up of the longitudinal dorsal and ventral sulcus on *Heteromys australis.* Claw samples are shown in the right side. Claw-sample analyzed (g), claws from rodents (h, i) and claws from bats (j - q).

Table 1. Claw comparisons among bats and rodents. In MECN 7430, finger and hand/foot position of claw are unknown.

Sample	Claw measurements	Finger I	Finger II	Finger III	Finger IV	Finger V	Range Mean ± SEM
Neacomys marci (MECN 6766)	Length	-	1.31	1.46	1.45	1.28	1.28 - 1.46 (1.38 ± 0.09)
	Width	-	0.27	0.22	0.22	0.23	0.22 - 0.27 (0.24 ± 0.02)
	Height	-	0.84	0.86	0.86	0.94	0.84 - 0.94 (0.88 ± 0.04)
Heteromys australis (MECN 7559)	Length	-	2.69	3.48	2.87	2.48	2.48 - 3.48 (2.88 ± 0.43)
	Width	-	0.37	0.47	0.4	0.44	0.37 - 0.47 (0.42 ± 0.04)
	Height	-	1.55	1.58	1.76	1.53	1.53 - 1.76 (1.61 ± 0.11)
Rhinophylla alethina (MECN 6803)	Length	3.27	3.07	3.07	3.06	3.03	3.03 - 3.27 (3.10 ± 0.10)
	Width	0.69	0.53	0.56	0.52	0.52	0.52 - 0.69 (0.56 ± 0.07)
	Height	2.14	2.07	2.17	2.04	2.02	2.02 - 2.17 (2.09 ± 0.06)
Sturnira ludovici (MECN 6804)	Length	4.01	4.08	4.12	4.19	4.12	4.01 - 4.19 (4.10 ± 0.08)
	Width	0.63	0.59	0.56	0.65	0.62	0.56 - 0.65 (0.61 ± 0.04)
	Height	2.43	2.35	2.51	2.32	2.56	2.32 - 2.56 (2.43 ± 0.10)
Vampyressa thyone (MEPN 12389)	Length	2.48	2.61	2.58	2.48	2.42	2.42 - 2.61 (2.51 ± 0.08)
	Width	0.38	0.36	0.38	0.35	0.39	0.35 - 0.39 (0.37 ± 0.02)
	Height	1.58	1.67	1.69	1.65	1.51	1.51 - 1.69 (1.62 ± 0.07)
Micronycteris megalotis (MEPN 5712)	Length	2.73	2.57	2.77	2.85	2.82	2.57 - 2.85 (2.75 ± 0.11)
	Width	0.37	0.42	0.43	0.49	0.41	0.37 - 0.49 (0.42 ± 0.04)
	Height	1.56	1.66	1.64	1.59	1.54	1.54 - 1.66 (1.60 ± 0.05)
Myotis riparius (MEPN 5250)	Length	1.99	2.61	2.58	2.51	2.18	1.99 - 2.61 (2.37 ± 0.27)
	Width	0.35	0.3	0.32	0.31	0.29	0.29 - 0.35 (0.31 ± 0.02)
	Height	1.55	1.6	1.69	1.46	1.57	1.46 - 1.69 (1.57 ± 0.08)
Myotis oxyotus (MEPN 10060)	Length	2.55	2.73	2. 84	2.67	2.64	2.55 - 2.73 (2.65 ± 0.08)
	Width	0.34	0.34	0.34	0.35	0.36	0.34 - 0.36 (0.35 ± 0.01)
	Height	1.84	1.62	1.83	1.66	1.59	1.59 - 1.84 (1.71 ± 0.12)
Thyroptera tricolor (MEPN 11135)	Length	1.85	2.05	2.07	2.09	1.71	1.71 - 2.09 (1.95 ± 0.17)
	Width	0.16	0.17	0.33	0.33	0.14	0.14 - 0.33 (0.22 ± 0.09)
	Height	1.13	0.65	1.15	1	0.65	0.65 - 1.15 (0.98 ± 0.23)
Peropteryx pallidoptera (MEPN 11135)	Length	2.51	2.36	2.1	2.39	2.38	2.1 - 2.51 (2.35 ± 0.15)
	Width	0.29	0.33	0.29	0.34	0.28	0.28 - 0.34 (0.31 ± 0.03)
	Height	1.98	1.93	1.9	1.97	1.99	1.9 - 1.99 (1.95 ± 0.04)
Claw obtained from a fecal sample of *Phyllostomus discolor* (MECN 7430)		Unknown finger	Unknown finger	Unknown finger	Unknown finger	Unknown finger	-
	Length	1.46	-	-	-	-	1.46
	Width	0.26	-	-	-	-	0.26
	Height	0.83	-	-	-	-	0.83

naked in *P. pallidoptera* and *T. tricolor* (Figure 2p, q). Our claw measurements were like those observed in *N. marci* rather than *H. australis* and bats (Table 1). In species like *T. tricolor,* claws of the fingers I and V are smaller than the rest of the fingers.

The 2 principal components of the PCA explained 96.3 % of the variation in the claw measurements, with claw length and claw height contributing to a greater extent to each one of them, respectively (Table 2). Our PCA analysis considers our claw sample to overlap in morphospace with *T.*

Table 2. Results of the Principal Component Analysis (PCA). The loadings with the highest absolute values in each component are bolded. The overall contribution of each component is shown between parentheses.

Claw Measure	PC1 (89.6 %)	PC2 (6.7 %)
Length	**0.5870635**	-0.089071
Width	0.5744845	-0.654447
Height	0.5703718	**0.7508435**

tricolor and to be related to *N. marci*. *S. ludovici*, *R. alethina, P. pallidoptera* and *M. riparius* did not overlap in morphospace (Figure 3a). *Myotis oxyotus, V. thyone,* and *M. megalotis* overlap with *H. australis.*

On the blackish materials found, we considered them to have a mineral origin instead of a vegetal origin. This because of their irregular shape, hard structure, difficulty to cut in half, and the absence of anatomic traits of seeds like hilum and funiculus, cotyledons, testa with scar patterns, micropyle, aril, and radicle tip. They were gravel of an unknown mineral composition (Figure 3b). We did not find other types of geological materials. Those pieces of gravel presented the remains of crushed insects on their surface. We found one unidentified seed (Figure 3c) and some remains of Coleoptera and Diptera (Figure 3d, e).

Despite the similarity in color, structure, and size between the anatomy of claw and hair spines sampled and those observed in museum voucher specimens of *N. marci*, we consider it better to maintain these findings as a potential record for mammal predation in *P. discolor*. We acknowledge the presence of some limitations in our study that must be discussed formally.

A common problem for researchers is that most of the time, the budget granted for research does not cover methods of molecular identification (Bradley *et al.* 2012). DNA metabarcoding as well as ancient DNA methods have been probed to detect the taxonomic identity of dietary items in fecal samples or ancient samples with a high degree of accuracy (Jones *et al.* 2020; Orlando *et al.* 2021). These methods are useful to understand the trophic niche composition of bats (Jones *et al.* 2020), but when they are not available, researchers are restricted to use traditional descriptive/comparative methods cited previously. So, the identification of comminuted remains of insects and small vertebrates in bats, in general, is complex because most of the remains are intermixed and only small parts persist. It is quite a puzzle challenge trying to put together the remains of digested items (Gardner 1977; Pokhrel and Budha 2015). It is an issue intensified by the habit of many bats to discard the harder and often more diagnostic parts of their prey, only the abdomens of lepidoptera and other large insects are commonly consumed, the rest is discarded (Gardner 1977). Researchers also have problems with the taxonomic identification of remains due to the lack of reference collections as well as field guides for seeds, insects, and vertebrates consumed by Neotropical bats (Gardner 1977; Rodríguez-Segovia 2022).

For the moment, we cannot assume *N. marci* as the identity of these remains because our comparisons were limited to certain mammals; we did not compare it with a large sample of rodents and bats, which would share similar traits found due to convergent evolution, or even with other vertebrates. However, this would be the third documented case of *P. discolor* preying on a small mammal, but the first one in natural conditions. Further comparative analyses are necessary given the single sample we analyzed.

Besides the limitations, studies that have found atypical feeding habits in bats would have several explanations, from simple aggression caused by interspecific competition, without motives of strict carnivory (Wine *et al.* 2019). Cannibalism caused by reasons of stress (see Tirira 2012), and predation caused by gathering different-sized species of mammals/bats in artificial conditions (Gardner 1977). To understand if *P. discolor* species preys on other vertebrates, new field-trip expeditions are needed. Even a formal revision of the stomach contents of museum specimens of *P. discolor* preserved in fluid and available in other natural history collections in national and foreign institutions is required.

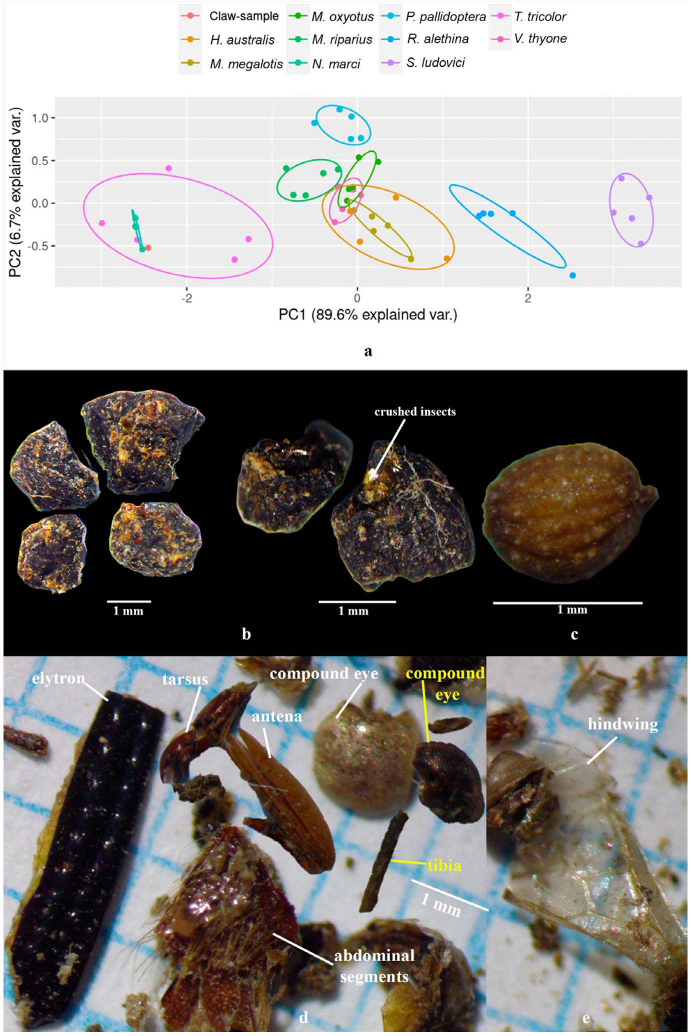

Figure 3. Results. a) Scatterplot of the Principal Components Analysis. b) Gravel found in *Phyllostomus discolor* fecal sample. c) Unidentified seed. d-e) Insect remains, the white lines show Coleoptera, and the yellow lines show Diptera remains.

Regarding our comparisons to determine the taxonomic identity of the mammal remains, many studies have evaluated the microscopic structure of hair and claws in mammals (Kondo 2000; Fleckman *et al.* 2013). However, there are insufficient studies on the macroscopic appearance of cricetid hair spines and bat claws. Mammalian hairs are broadly variable in shape and structure, and this variation is related to each species, climates, adaptations, their functions in organs, body position, populations, and alleles (Kondo 2000; Meyer *et al.* 2002; Buffoli *et al.* 2014). Furthermore, the observed claw-size similarities and differences may be related to the roosting and fossorial habits of bats and rodents because the evolution, together with different lifestyles and habits, has influenced the form and function of claws in mammals (Maiolino *et al.* 2011). In summary, all of this variation makes it difficult to identify these types of remains with traditional methods.

On the gravel found in the sample, there are 2 scientific theories when analyzing these findings. Bats are commonly reported to eat clay from mineral licks as a part of a detoxification process because many plants on which they depend are heavily defended with toxic substances, that is, alkaloids; clay also counters the effects produced by endoparasites; and it has nutritional benefits due to the addition of certain minerals, such as: sodium, calcium, copper, iron, and zinc (Knezevich 1998; Engel 2007; Voigt *et al.* 2008; Downs *et al.* 2019). However, Gardner (1977) suggested that materials found in the stomachs of carnivorous and omnivorous bats may be misleading. Because the remains of fruits, seeds, insects, bits of sand or gravel may have been consumed by an animal before being ingested by the bat itself. This is also applicable to the sample obtained in this study.

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Appendix 1

Details of specimens used for this research.

Ecuador

-Carchi: *Neacomys marci* MECN 6233: Reserva Drácula, 1030 m (1° 0′ 8.2″ N, 78° 13′ 19.2″ W).

-**Esmeraldas**: *Heteromys australis* MECN 7559: Eloy Alfaro, Telembi, Gualpí de las Cayapas, 250 m (0° 33′ 44.7″ N, 79° 4′ 19.5″ W). *Heteromys australis* MEPN 5749: 2.5 km al Sur de Luis Vargas Torres, 100 m (0° 52′ 42″ N, 78° 47′ 32″ W).

-Imbabura: *Heteromys australis* MEPN 11717 and *Neacomys marci* MEPN 11720: Cotacachi, Cielo Verde, 540 m (0° 13′ 33.6″ N, 78° 54′ 50.4″ W).

-Manabí: *Myotis riparius* MEPN 5250: Puerto López, Espuela Perdida, 2 km al E de La Mocora, Parque Nacional Machalilla, 100 m (1° 37′ 0″ S, 80° 42′ 0″ W).

-**Morona Santiago:** *Micronycteris megalotis* MEPN 5712: Morona, Uuntsuants Centro Shuar, Cordillera del Kutukú, 600 m (2° 33′ 9″ S, 77° 53′ 48″ W).

-**Napo**: *Myotis oxyotus* MEPN 10060: Quijos, Cuyuja, La Victoria, 2775 m (0° 24′ 7.2″ S, 78° 1′ 4.8″ W).

-**Pastaza**: *Vampyressa thyone* MEPN 12389: Arajuno; Lorocachi Parque Nacional Yasuní, 219 m (1° 36′ 46.9″ S, 75° 58′ 0.5″ W).

-Pichincha, Quito [Pacto]: *Rhinophylla alethina* MECN 6803 and *Sturnira ludovici* MECN 6804: Mashpi Lodge, 916 m (0º 9′ 58″ N, 78° 52′ 51.7″ W) and 932 m (0° 9′ 58.4″ N, 78° 52′ 57.2″ W), respectively. *Phyllostomus discolor* MECN 7430: San José de Mashpi-Reserva Mashpi Shungo, bosque secundario, 634 m (0° 11′ 20.1″ N, 78° 54′ 48.8″ W). *Neacomys marci* MECN 6766: Comunidad de Mashpi [Chontaloma], 629 m (0° 10′ 53″ N, 78° 54′ 18.6″ W).

-Sucumbíos: *Peropteryx pallidoptera* MEPN 9913: Lumbaqui, Río Aguarico, confluencia con el río Puchucchoa, a 20 km de la población de Lumbaqui, 425 m (0° 2′ 4.2″ N, 77° 24′ 13.9″ W).

-Zamora Chinchipe: *Thyroptera tricolor* MEPN 11135: El Pangui, Cóndor Mirador, Destacamento Militar, 1665 m (3° 38′ 8″ S, 78° 23′ 22″ W).