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Short Note

Víctor Romero* and Scott C. Pedersen

A new abnormality record in bats: a teratological condition or skull trauma due to tooth avulsion in *Noctilio leporinus*?

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Abstract: Here we report on a skull of an adult male *Noctilio leporinus* caught in the Guiana Shield, South America. The animal was lacking the upper left molar-row and exhibited skeletal deformations in the rostral and palatal regions. This aberration could have been the result of a traumatic avulsion of the left C1. As a consequence of its position and depth of the root, the C1 avulsion could have broken much of the surrounding alveolar process during the initial injury, with subsequent loss of the remaining teeth via periodontal inflammation and tooth decay.

Keywords: aberration; Chiroptera; deformity; Guiana shield; Neotropical mammals; tooth decay; Venezuela.

Historically, many abnormalities were perceived as mythological or fantastic monstrosities extracted from ancient bestiaries (see examples in Wittkower 1942). Teratology is a science that studies the origins, patterns, and mechanisms subjacent to abnormal development (Ujházy et al. 2012). In fact, its etiology and causes are relatively well known for humans and some domestic mammals (Kompanje 2005). However, abnormalities in wild mammals have been poorly reported in the literature, in part because the majority of the affected individuals are aborted early in development and the few born generally do not reach maturity (Kunz and Chase 1983). This is especially the case if these abnormalities affect vital systems, such as heart, kidney, brain, digestion, sensory perception and even locomotion.

The malformations reported in bats have been attributed to multiple causes, including genetic mechanisms, pathogenic and traumatic causes, or even stress. Many of them are associated to specific developmental stages, such as congenital abnormalities like conjoined twins reported for *Eptesicus fuscus* (Beauvois, 1796) (Peterson and Fenton 1969), *Artibeus phaeotis* Miller, 1902 (Urban et al. 2015) and *Artibeus* sp. (Nogueira et al. 2017); deformed tails in *E. fuscus* (Kunz and Chase 1983) and *Tadarida brasiliensis* I. Geoffroy, 1824 (Mitchell and Smith 1966); dental anomalies recorded for more than 50 species (e.g. supernumerary teeth, see Lanza et al. 2008 for a review), fur chromatic disorders such as albinism, melanism and leucism not related to aging, reported for more than 115 species by many authors (recently reviewed by Lucati and López-Baucells 2016, Zalapa et al. 2016, Rose et al. 2017, Zortéa and Silva 2017, but see Romero and Tirira 2017 for a note in phenotype nomenclature in mammals), polydactyly reported in *A. lituratus* Olfers, 1818 (Gonçalves et al. 2011), *T. brasiliensis* (Koford and Krutzsch 1948, Herreid 1958) *Pipistrellus subflavus* (F. Cuvier, 1832) (Jennings 1958), *E. furinalis* (Kunz and Chase 1983), and *Myotis velifer* (J.A. Allen, 1890) (Caire and Thies 1988, Pekins 2009); an anomalous skeletal appendage in *E. fuscus* (Dalby 1969, Kunz and Chase 1983); a polyotia report in *A. lituratus* (Ruckert da Rosa et al. 2011) or supernumerary appendages in *P. pipistrellus* (Hackenthal and Grimmberger 1978). Others can occur in later developmental stages, like the reduction in teeth caused by external factors such as environmental, traumatic and nutritional causes (Phillips and Jones 1968, Pedersen et al. 2012) or deformed forearms resulting from poorly healed fractures of the radius in *E. fuscus* (Hofstede et al. 2003) and *M. brandtii* (Eversmann, 1845) (Bogdanowicz and Urbanczyk 1986). In wild populations, these conditions appear to be uncommon, even in the case of less severe abnormalities, that apparently do not notably affect the survival rate, but generally have a very low reported incidence. For example, Mitchell and Smith (1966) detected only two individuals with deformed tail from a sample of

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150,000 Mexican free-tailed bats (*T. brasiliensis*). In bats, just a few distinct kinds of developmental abnormalities have been reported, which contrasts with more than 1700 types reported in laboratory mammals (i.e. rats, mice, rabbits; Makris et al. 2009).

Here we describe the skull and teeth of a single *Noctilio leporinus* Linnaeus, 1766 collected in the Guiana Shield. This skull exhibits a severe anatomical alteration of the upper alveolar processes and the mandible on the left side of the skull.

The Guiana Shield ecosystems in northern South America are unique and hold a rich flora and fauna, with an exceptional and underestimated degree of endemism, particularly in the highlands (Bonaccorso and Guayasamin 2013). At the landscape scale, it is characterized by the presence of tepuis, i.e. sandstone flat-top mountains with vertical cliffs that rise more than 1000 m a.s.l. above the lowland Amazonian woods and Guiana grasslands (Huber 1988). From the about 100 known tepuis, around 90 are located in southern Venezuela, while the remnant 10 are in Western Guyana and Northern Brazil (Salerno et al. 2015).

The Canaima National Park is situated in the north-eastern part of the Guiana Shield, Guayana, Venezuela, between the coordinates 04°41' and 06°48' north and 60°44' and 62°59' west (Figure 1). Some of the larger tepuis, such as Auyán-tepui, and the world's highest uninterrupted waterfall, the Angel Falls (979 m, Figure 2), are located in Canaima. In this park, more than 151 species of mammals coexist (Lew et al. 2009), representing 60% of those reported for Guiana (i.e. 251 species sensu Lim et al. 2005) and 40% of those recorded in Venezuela (i.e. 341 species sensu Sánchez and Lew 2012). From the mammalian species reported in Canaima, 49% are bats, one of them being *Noctilio leporinus*.

The greater bulldog bat, *Noctilio leporinus*, is a large bat, endemic to and widely distributed in the Neotropics. It is a piscivorous species but will also eat large insects and invertebrates (Brooke 1994). It exhibits several important anatomical adaptations specific to its feeding habits. The most evident traits of this species include: absence of a nasal leaf; upper lip deeply cleft medially; dental formula I 2/1, C 1/1, P 1/2, M 3/3; very short and dense fur; wings that attach to the body dorsally and not laterally as in most chiropterans;

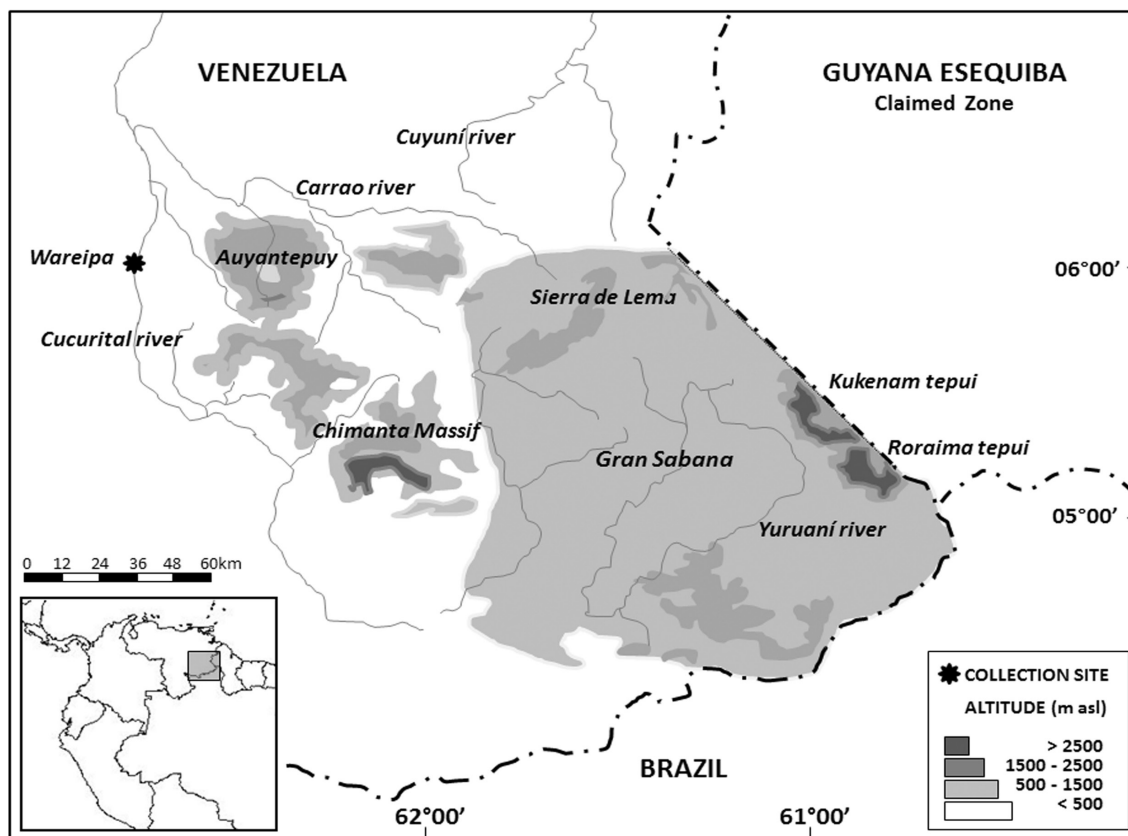


Figure 1: Canaima National Park, Bolívar state, Venezuela, at the northeastern sector of the Guiana Shield, South America, includes the record location Raudal Wareipa, Rio Cucurital (06°00'52"N, 62°47'42"W; 390 m a.s.l.).

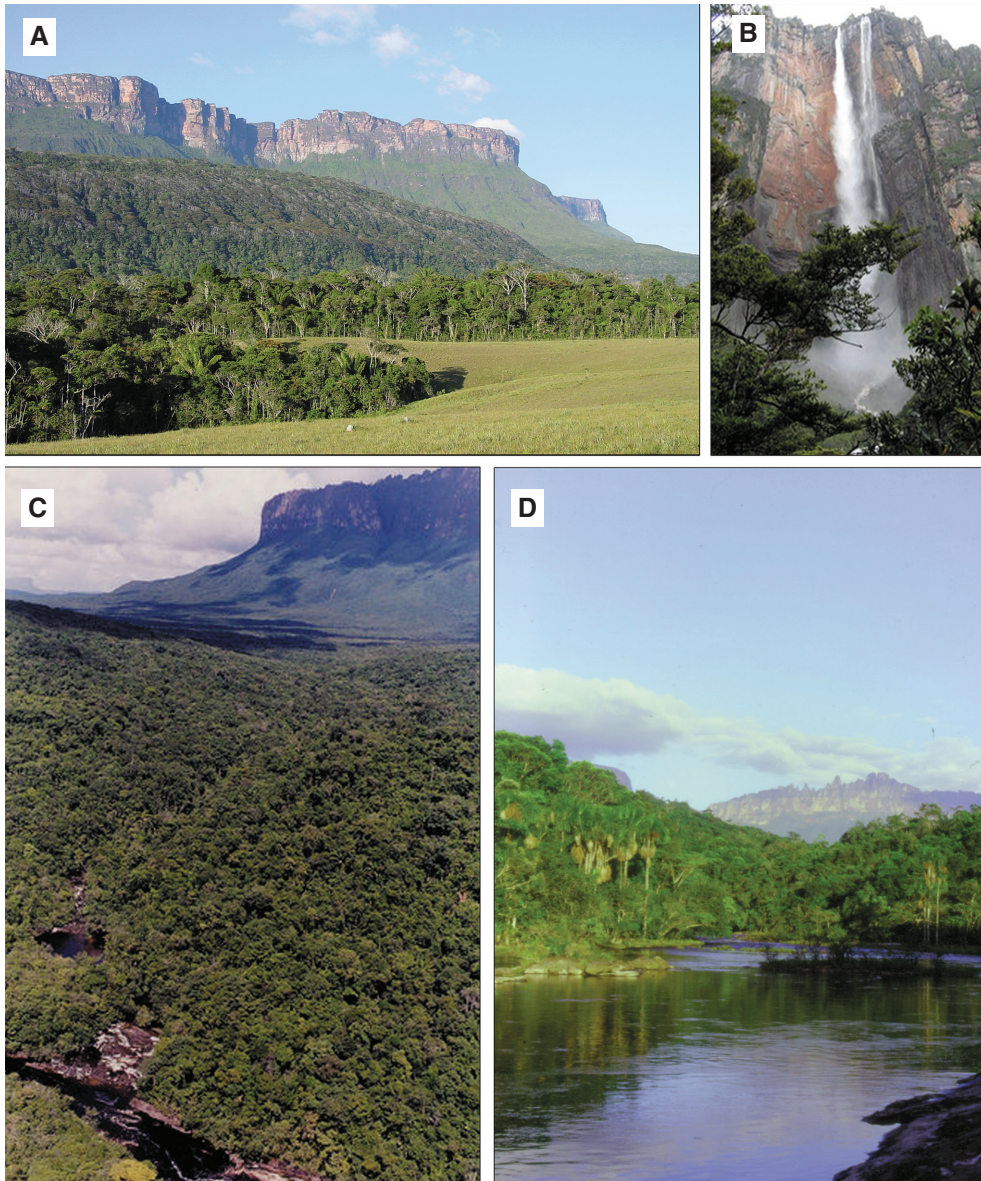


Figure 2: Some relevant sites in Canaima National Park, Bolívar state, Venezuela, South America: Auyan-tepui (A) and Angel Falls (B). The Wareipa River originates from Auyan-tepui and flows in the Cucurital River (C) upstream of the record location, Raudal Wareipa (D). Photo credits: (A) and (D) by Celsa Señaris, (C) by Giuseppe Colonnello, and (B) by Víctor Romero.

coat coloration varies from brown to orange, usually with a clear line along the dorsal region. It possesses a short tail that protrudes dorsally from the interfemoral membrane. Although *N. leporinus* and its sibling species *Noctilio albiventris* exhibit a great similarity in morphology (Hood and Jones 1984), they differ greatly in size, *N. leporinus* (forearm length >83 mm) being significantly larger than *N. albiventris* (forearm length <69 mm).

The specimen of *Noctilio leporinus* (MHNLS 10988) with the aberrant skull is housed in the Museo de Historia Natural La Salle, Caracas, Venezuela. The specimen is an adult male (weight 66 g; forearm length 87.8 mm), collected

by I. Jiménez (field number AFP-1091) at Raudal Wareipa, Rio Cucurital, Canaima National Park, Guayana region, Bolívar state, Venezuela (06°00'52"N, 62°47'42"W; 390 m a.s.l), on 13 April, 1999 (Figure 2). The specimen was shot with a 16 gage shotgun from a boat on the Cucurital River and preserved as dry skin and skull. MHNLS 10988 is the only specimen of *N. leporinus* reported for Canaima (Lew et al. 2009). In a broader research context (Romero 2011), the skin and skull of this specimen was compared with 900 vouchers of the two recognized *Noctilio* species, including 220 *N. leporinus*, which correspond to most of the distributional range and morphological variation currently known

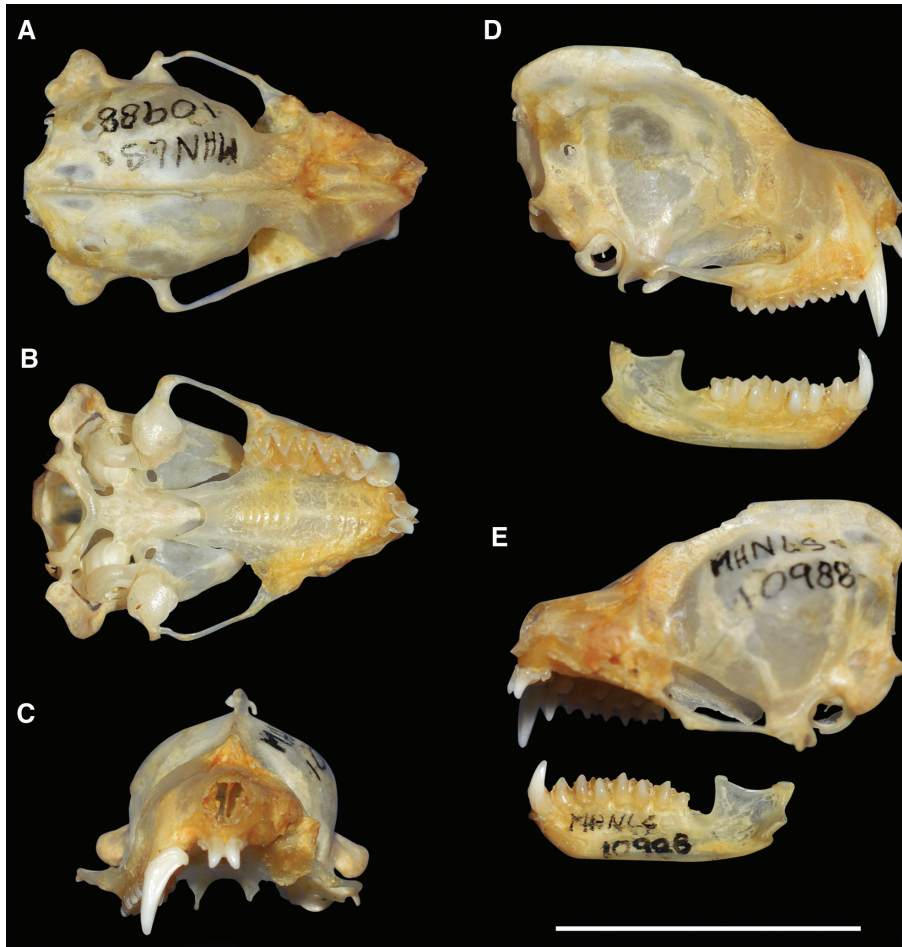


Figure 3: Dorsal (A), ventral (B), rostral (C) view of the skull, and the right (D) and left (E) side of the skull and dentary, in an aberrant *Noctilio leporinus* (MHNLS 10988) from Wareipa, Río Cucurital, Parque Nacional Canaima, Venezuela.

Note that the skull was lacking the upper left molar-row and exhibited anatomical deformities in the rostral and palatal regions.

for the species. MHNLS 10988 matches the description of *N. leporinus* and fits the morphologic pattern, except for the anomalies here described. Although there is morphological (Davis 1973) and molecular evidence (Awarali-Khan et al. 2013) that supports the recognition of three subspecific forms within *N. leporinus* (*N. l. leporinus*, *N. l. mastivus* and *N. l. rufescens*), the morphological delineation of these subspecies and their geographical limits are unclear for some areas. In this case, the specimen MHNLS 10988 comes from a locality within the geographical limits established by Davis (1973) for two of these forms: *N. l. leporinus*, found in the Guianas and the Amazon lowlands, except Venezuela; and *N. l. mastivus* that occurs in northwestern Guyana, southward throughout the Río Orinoco and Río Negro drainage basin of southern Venezuela, in Colombia lowlands up to Ecuador.

Noctilio leporinus is sexually dimorphic and the morphological data presented by Davis in his revision are

based only on female specimens. In this context, we do not assign this specimen to any subspecies until a revision that clarifies the subspecific distribution of *N. leporinus* in Venezuela will be available.

Selected cranial measurements (in millimeters) of MHNLS 10988 are: greatest length of skull, 26.57; condylobasal length, 24.01; basal length, 21.64; palatal length, 13.72; inter-orbital breadth, 6.66; braincase breadth, 13.59; right-side maxillary tooth row-length, 12.23; mandibular length, 19.51 and right-side mandibular tooth row-length, 11.38. The skull of the specimen MHNLS 10988 (Figure 3) exhibits deformations in the rostral and palatal regions. The left maxillary is laterally overcrowded, bulky and irregular, and the characteristic latero-ventral margin of the jaw is not evident on this side. The upper premolar (P1) and molars (M1–3) series is absent except for the M2, which shifts laterally to the base of the zygomatic process. Its alveoli are the only ones that remain visible in the left

maxillary bone. Therefore, we can infer that this molar was functional and probably was lost during the cleaning of the skull. The zygomatic process of the maxilla is upwardly displaced and laterally curved; the jugal bone and the process of the squamosal in the temporal region are reduced. Probably as a consequence of the reduction of the alveolar process and the subsequently reduction in the anterior floor of the orbit, the orbital region looks elongated and curved when observed dorsally. The lack of teeth on the left side could imply a poor masticatory capacity and induce the atrophy of one or both heads of the masseter muscles, which in turn could explain the deformation of the zygomatic arch. The body of the left dentary appears deeper and its alveolar process is much taller as a result of the overeruption of teeth. No scars or anomalies were detected in the dry skin.

The magnitude of this deformation suggested that this was a teratologic consequence of a congenital disorder. But during mammalian development, the absence of the teeth on one side of the mandible leads to underdevelopment of the associated bones (i.e. the alveolar ridge, maxilla, mandible and postglenoid processes of the temporal-mandibular joint) and respective asymmetry by overcompensation of the bones involved in the transmission of masticatory force such as the nasal bones and pre-maxillae (Rosen et al. 1965). This condition has been reported for other wild mammals (e.g. in the common seal, *Phoca vitulina*, Suzuki et al. 1992 and the white-tailed deer, *Odocoileus virginianus*, Jenks et al. 1986). There are no similar reports in bats.

The apparent absence of compensatory asymmetry in any of the four palatal elements and the fact that there is no evidence of midline deviation in the inter-nasals, in the inter-premaxillary or the inter-maxillary sutures suggest that the observed anomaly occurred later in development, rather than as a congenital abnormality. One possible scenario is that the deformation was the result of the posterolateral avulsion of the left C1. As a consequence of the position and the depth of the root of this tooth, its avulsion could have broken or detached much of the buccal alveolar process during the initial injury. Subsequent loss of the remaining teeth (except M2) would then occur via periodontal inflammation and tooth decay development. The incidence of acute caries by itself can result, in many cases, in the loss of one or more teeth (Phillips and Jones 1970). The loss of superior teeth and the elimination of the mechanical restriction imposed by occlusal contact induced the over-eruption of M1–3. The body on the left dentary is clearly much deeper than that on the right, its occlusal plane being located above the mandibular notch, although it is normally articulated with the skull.

Dental fracture, avulsion, and loss was observed in approximately 5% of the 220 *Noctilio leporinus* mentioned previously. This damage included the fracture of one or two canines, seven specimens with a single C1 and four specimens with both C1 fractured. Similarly, on the Island of Culebra, Puerto Rico, Anne Brooke found specimens fishing bats even with all four of their canines broken (personal communication). One possible explanation is that these bats feed on mudflat fiddler crabs, *Uca rapax*, whose claws are large, durable, and capable of fracturing a tooth (Brooke 1994). In kind, collisions with overhead obstacles or with floating debris, during the search for prey on the surface of the water, could also fracture or dislodge any of the four canines.

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