Bone fractures in roadkill Northern Tamandua
*Tamandua mexicana* (Mammalia: Pilosa: Myrmecophagidae) in Costa Rica

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Abstract: Northern Tamandua Tamandua mexicana is one of the most common roadkill species encountered on Costa Rican highways. Ten roadkill Northern Tamanduas were collected along different roads in Costa Rica and moved to a veterinary facility where appendicular radiologic studies were undertaken. The number of fractures present in each individual varied from zero to five (mean=2.6), with only one animal sustaining no fractures at all. Most fractures were present in the humerus (31%), followed by the ulna and ilium (both 19%), whilst the cranial portion of the body represented the highest number of fractures (61%). These data can contribute, not only to establishing causes of animal-road-mortalities, but also to the future understanding and decision-making of clinical actions for animals injured on the roads.

Keywords: Anteater, car accidents, radiology, roadways, wildlife mortality.

Resume: El tamandúa norteño Tamandua mexicana es una de las especies que más comunes que se encuentran atropelladas en las carreteras de Costa Rica. Se recolectaron diez tamandúas atropelladas a lo largo de diferentes caminos en Costa Rica y se trasladaron a una clínica veterinaria donde se realizaron estudios radiológicos apendiculares. El número de fracturas presentes en cada individuo varió de cero a cinco (media = 2.6), y solo un animal no sufrió fracturas del todo. La mayoría de las fracturas estaban presentes en el húmero (31%), seguidas por la ulna y el ilion (ambos 19%); la porción craneal del cuerpo representaba el mayor número de fracturas (61%). Estos datos pueden contribuir, no solo al establecimiento de causas de mortalidad de animales en el camino, sino también a la comprensión y toma de decisiones futuras de acciones médicas para animales que son heridos en carreteras.
INTRODUCTION

Highways are significant factors of wildlife mortality; they interfere with natural migration routes and are responsible for habitat fragmentation, which is one of the main causes of biodiversity loss (De la Ossa-V & Galván-Guevara 2015). A further negative impact of roads is the resulting collision with a vehicle, namely, roadkill.

Studies have shown that roadkill seriously decreases animal populations and can even result in local extinctions creating a risk factor for xenarthran persistence, even to non-threatened species (Ribeiro et al. 2017). Among Costa Rican wildlife species, the Common Opossum *Didelphis marsupialis* and a species of anteater *Tamandua mexicana* (Image 1) dominate roadkill numbers (Monge-Nágera 2018b).

Monge-Nágera (2018a) found that *T. mexicana* was the most common roadkill species (n=73), followed by the Common Opossum (n=66) from data gathered over a four year period (2014–2018). Furthermore, 13 additional *T. mexicana* individuals were detected as roadkill over a one-year period (48 sample efforts) on a 94.9km road (n=7.3 anteater/km) (Artavia et al. 2015) whilst a further seven individuals of *T. mexicana* were found on a 100-km section of road over an eight-month period in 2008 (Carvajal Alfaro & Díaz Quesada 2016).

*T. mexicana* had higher numbers of roadkill during the dry season (December to April) than the wet season (May to November) in Costa Rica and Colombia (Nadjar & De la Ossa 2013; Monge-Nágera 2018a) possibly because ants are scarcer in dryer habitats than when it is wet, causing anteater species to travel further in search of food. This may result in them crossing roads more frequently and becoming roadkill although this is just speculation since the seasonal behavior of *T. mexicana* is poorly known (Nadjar & De la Ossa 2013; Monge-Nágera 2018a) and further study of their behaviour is needed (Monge-Nágera 2017, 2018a).

Descriptive epidemiological studies of wildlife are an important source of information about natural and non-natural hazards to wildlife populations (Molina-López et al. 2011) and consequently, studies that investigate the causes of mortality have become an important source for ecosystem health monitoring (Molina-López et al. 2011). One of the most common findings in animals hit by automobiles is the appendicular fractures (Minar et al. 2013) which can be surgically treated if an injured animal is taken to a rescue center. Understanding the normal

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**Image 1. Northern Tamandua *Tamandua mexicana* at Aranjuez, Pitahaya, Puntarenas Province, Costa Rica.**

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bone radiographic appearance as well as the location of the fracture is vital in assisting the treatment of injured animals. Furthermore, increased public awareness of the number of wildlife injured or killed on Costa Rican roads may have contributed to the mitigation methods being applied.

*T. mexicana* is a species of a medium-sized anteater ranging from southern Mexico to northwestern Andes in South America and lives in diverse forest ecosystems (Navarrete & Ortega 2011). It is classified as “Least Concern” by the IUCN due to its wide distribution, and presumably, large population, however, the current population trend is unknown (Ortega et al. 2014), although it is represented in protected areas, as well as in anthropogenic ecosystems (Navarrete & Ortega. 2011). Usually solitary by nature, *T. mexicana* ranges often overlap with that of neighboring *T. mexicana*. Females give birth to a single offspring once a year, with the pups becoming independent after one year (Wainwright 2007; Navarrete & Ortega. 2011). Head and body length ranges from between 470–770 mm, with a tail length between 402–672 mm; weight ranges from 2–7 kg (Nowak 1991; Wainwright 2007). *T. mexicana* is both diurnal and nocturnal foraging in trees and on the ground, feeding predominantly on termite genera: (Armintermes, Calcaritermes, Coptotermes, Leucotermes, Microcerotermes, and Nasutitermes; Navarrete & Ortega 2011) and ant genera (Camponotus, Azteca, and Crematogaster; Navarrete & Ortega 2011)

The purpose of this communication is to use roadkill *T. mexicana* as tools to demonstrate the location and frequency of bone fractures resulting from an impact with a vehicle. This information can be a valuable reference in future medical and surgical procedures at rescue centers.

**METHODS**

Ten roadkill of *T. mexicana* were collected between April to July 2016, on different roads in Costa Rica. For each individual, the date and time of collection, geographic coordinates and the person responsible for collecting them were recorded. We believe that two of the animals were at least one year old. The remaining eight individuals consisted of mature animals based on closed epiphyseal growth plates. Based on the presence of the reproductive organs, we were able to sex three of the *T. Mexicana* confirming there were two females and one male; three of the carcasses had no organs, whilst the remaining four individuals were unclear due to damage to the abdominal cavity.

The 10 *T. Mexicana* (all deceased) were transferred to a veterinary establishments where appendicular radiology studies were carried out using an Ultra 12040HF (Diagnostic Imaging Systems®) X-ray unit with a CR2000 Plus Scanner and CR200 Navigator Software (Diagnostic Imaging Systems®). Lateral (L) and anteroposterior (AP) orthogonal views of the four extremities were taken. Each animal received six radiographs, with AP projections of the forelimbs and hind limbs performed on both limbs at the same time. Each affected bone, in all animals, had only one fracture, which made further classification easier. For two of the animals, x-rays of the hind legs could not be done due to extensive damage to the legs. For the remaining eight, x-rays of the forelimbs (including the scapula, humerus, radius/ulna, carpus, metacarpals, and phalanges) and x-rays of the hind limbs (including the ilium, ischium, pubis, femur, tibia and fibula, tarsals, metatarsals and phalanges) were all taken.

**RESULTS**

Of the 10 roadkill, a total of 54 radiographs were taken (Figures 1 & 2). Two individuals had open epiphyseal growth lines indicating that they were juveniles and still growing. The number of fractures present in each individual varied from zero to five (mean=2.6); only one animal did not present any fractures, while three of them had a total of five fractures in different bones (Table 1). Sixty-one percent of the fractures occurred in the cranial portion of the body with the majority observed in the humerus (31%) followed by the ulna (19%) and then the radius (11%). The remaining 39% were present in the caudal portion of the body with the majority observed in the ilial (19%), followed by the femur (12%) and then tibia/fibula (8%); no fractures were observed in the scapula, ischium, pubis, carpal/tarsal, metacarpal/tarsal and phalanges.

**DISCUSSION**

There are few studies that utilize road-killed animals as a beneficial tool for learning, specifically for evaluating fractures on animal-roadkill species. Most studies that evaluate roadkill-animal-fractures mainly focus on domestic animals (for example, dogs and cats) (Minar et al. 2013; Martínez-Hernández et al. 2017). Despite cats having a similar head and body length (that is, ~460mm) as the *T. mexicana*, our study observed that a higher
Table 1. Fractures per individual of the ten roadkill *T. mexicana* collected between April to July 2016, on different roads in Costa Rica.

| Individual | LH | RH | LR | RR | LU | RU | LF | RF | LT | RT | LI | RI | Total |
|------------|----|----|----|----|----|----|----|----|----|----|----|----|-------|
| T1         | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 0     |
| T2         | -  | 1  | 1  | -  | 1  | -  | -  | 1  | -  | -  | 1  | -  | 5     |
| T3         | 1  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 1     |
| T4         | -  | -  | -  | -  | 1  | -  | -  | -  | -  | 1  | 1  | -  | 3     |
| T5         | 1  | 1  | 1  | 1  | 1  | -  | x  | x  | x  | x  | x  | x  | 5     |
| T6         | -  | -  | -  | -  | -  | 1  | -  | 1  | -  | -  | -  | -  | 2     |
| T7         | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 1  | -  | 1     |
| T8         | -  | 1  | -  | -  | 1  | -  | x  | x  | x  | x  | x  | x  | 2     |
| T9         | 1  | 1  | -  | -  | -  | -  | -  | 1  | -  | -  | 1  | 1  | 5     |
| T10        | -  | 1  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 2     |
| Total overall | 3  | 5  | 1  | 2  | 2  | 3  | 0  | 3  | 0  | 2  | 3  | 2  | 25    |

Key: L—left | R—right | H—humerus | R—radius | U—ulna | F—femur | T—tibia | I—ilium. Individuals T5 and T8 have no hind limb x-rays (x) | --- means no fractures | X—means the individuals did not have the limb.
percentage of fractures were found in the cranial portion of the *T. mexicana* whilst the most commonly affected bones in cats were found in the caudal portion (such as, the femur (28.2%) and pelvis (24.8%). The same contrast was also noticed with dogs with more fractures observed in the pelvis (15.8%), the femur (14.8%) and the tibia (14.8%) (Phillips 1979). Reasons for a higher percentage of fractures found in the cranial portion of the *T. mexicana* is likely due to a combination of dense roadside habitat and the anatomy of xenarthrans whose plantigrade locomotion, coupled with short limbs, provides low agility and relatively slow locomotion (Ribeiro et al. 2017). They emerge from the forest onto the road, providing a driver with limited visibility ad reaction time, and are often immediately hit by a vehicle in the frontal lateral position (Ribeiro et al. 2017).

Other reasons for xenarthrans being vulnerable to roadkill are their poor vision, which may mean they simply do not see approaching vehicles (Ribeiro et al. 2017). Furthermore, speeding vehicles and poor driver visibility (particularly in areas with dense roadside vegetation) may also influence roadkill occurrence (Collinson et al. 2019).

Similar findings for fractures found on roadkill and comparable with *T. mexicana* is a study undertaken in North America, where an average of four fractures per individual in Virginia opossums *Didelphis virginiana* were observed (Mead & Patterson 2009). This species is a medium-sized mammal, with head and body length ranging from 325 to 500 mm, weighing between 2–5.5 kg (Novakl 1991) and thus similar to the *T. mexicana*. Mead & Patterson (2009) reported several findings for opossums collected on roads, where the majority of skeletal injuries occurred in the cranial portion of the skeleton (for example, 54% rib fractures and 23% scapular fractures). Similar to the findings of Mead & Patterson (2009) on opossums, we also observed more than one fracture per individual in *T. mexicana*; this is likely due to them being of medium-sized resulting in multiple fractures when colliding with a vehicle (Cross 2012).
CONCLUSION

We found little literature evaluating long bone radiology in *T. mexicana*, therefore the data from our study which provides examples (and images) of normal appendicular x-rays plus the anatomic bone fracture location of trauma, can be used as a reference for further medical or biological studies, specifically at rescue and rehabilitation centers.  Veterinarians can use epidemiological information to better understand surgical treatment of *T. mexicana* (and other species of similar size and behaviour), particularly for injured individuals that can then be rehabilitated and released back into the wild.

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Announcement

The Sally Walker Conservation Fund – an appeal for support
– P. 14787

Communications

Complementary bat (Mammalia: Chiroptera) survey techniques uncover two new country records for Nigeria
– Iroro Tanshi, Anthony Ekata Ogbeibu & Paul Jeremy James Bates, Pp. 14788–14801

Bone fractures in roadkill Northern Tamandua Tamandua mexicana (Mammalia: Pilosa: Myrmecophagidae) in Costa Rica
– Randall Arguedas, Elisa C. López & Lizbeth Ovares, Pp. 14802–14807

Barilius torsi (Teleostei: Cypriniformes: Cyprinidae), a new freshwater fish from the Brahmaputra drainage, India
– Kavita Kumari, Manas Hoshalli Munivenkatappa, Archana Sinha, Simanku Borah & Basanta Kumar Das, Pp. 14808–14815

Butterfly diversity throughout Midnapore urban area in West Bengal, India
– Surjyo Jyoti Biswas, Debarun Patra, Soumyajit Roy, Santosh Kumar Giri, Suman Paul & Asif Hossain, Pp. 14808–14826

Plant and fungi diversity of Devi Pindiyan Valley in Trikuta Hills of northwestern Himalaya, India
– Sajan Thakur, Harish Chander Dutt, Bikarma Singh, Yash Pal Sharma, Nawang Tashi, Rajender Singh Charak, Geeta Sharma, Om Prakash Vidyarthi, Tasir Iqbal, Bishander Singh & Kewal Kumar, Pp. 14827–14844

A checklist of rust fungi from Himachal Pradesh, India
– Ajay Kumar Gautam & Shubhi Avasthi, Pp. 14835–14861

The distribution of blue-green algae (Cyanobacteria) from the paddy fields of Patan and Karad tehsils of Satara District, Maharashtra, India
– Sharada Jagannath Ghadage & Vaneeta Chandrashekhar Karande, Pp. 14862–14869

Short Communications

Cordia diffusa K.C. Jacob, the Koval Manjack (Boraginaceae): a highly threatened steno-endemic species from Coimbatore City, Tamil Nadu, India
– S. Arumugam, K. Sampath Kumar, B. Karthik & V. Ravichandran, Pp. 14870–14875

New distribution records in the orchid flora of Tripura, India
– Arjun Adit, Monika Koul & Rajesh Tandon, Pp. 14876–14885

Notes on the extended distribution of Humboldtia bourdillonii (Fabales: Fabaceae), an Endangered tree legume in the Western Ghats, India
– Anoop P. Balan, A.J. Robi & S.V. Predeep, Pp. 14886–14890

Notes

Vertebrate prey handling in the Indian Grey Hornbill Ocyeros birostris (Aves: Bucerotiformes: Bucerotidae)
– James A. Fitzsimons, Pp. 14891–14894

Impact of cyclone Fani on the breeding success of sandbar-nesting birds along the Mahanadi River in Odisha, India
– Subrat Debata, Pp. 14895–14898

First record of the micromoth Ethmia lineatonotella (Moore, 1867) (Lepidoptera: Depressariidae: Ethmiinae) from Bhutan
– Jatishwor Singh Irungbam & Meenakshi Jatishwor Irungbam, Pp. 14899–14901

Additional distribution records of the rare Nepal Comma Polygonia c-album aegnula (Insecta: Lepidoptera: Nymphalidae) from Rara National Park, Nepal
– Sanje Prasad Suwal, Biraj Shrestha, Binita Pandey, Bibek Shrestha, Prithivi Lal Nepal, Kaashi Chandra Rokaya & Bimal Raj Shrestha, Pp. 14902–14905

A new distribution record of the gall midge Octodiplosis bispina Sharma (Diptera: Cecidomyiidae) from the Western Ghats of Tamil Nadu, India
– Duraikannu Vasanthakumar, Radheshyam Murlidhar Sharma & Palanisamy Senthilkumar, Pp. 14906–14907

New recruitment of staghorn corals in the Gulf of Mannar - the emergence of a resilient coral reef
– Koushik Sadhukhan, Ramesh Chatragadda, T. Shanmugaraj & M.V. Ramana Murthy, Pp. 14908–14911

New records of coral diseases in the Persian Gulf
– Parviz Tavakoli-Kolour & Sanaz Hazraty-Kari, Pp. 14912–14913

Crepidium aphyllum (Orchidaceae), a new record from Bhutan (Diptera: Cecidomyiidae) from the Western Ghats of India
– Subrat Debata, Pp. 14923–14926

Additional distribution records of the rare Nepal Comma Polygonia c-album aegnula (Insecta: Lepidoptera: Nymphalidae) from Rara National Park, Nepal
– Jatishwor Singh Irungbam & Meenakshi Jatishwor Irungbam, Pp. 14923–14926

New recruitment of staghorn corals in the Gulf of Mannar - the emergence of a resilient coral reef
– Koushik Sadhukhan, Ramesh Chatragadda, T. Shanmugaraj & M.V. Ramana Murthy, Pp. 14908–14911

Notes

New distribution records in the orchid flora of Tripura, India
– Arjun Adit, Monika Koul & Rajesh Tandon, Pp. 14876–14885

On the floral biology and pollination of a rare Twining Liana Sarcolobus carinatus Wall. (Asclepiadoideae: Apocynaceae) in Coringa Mangrove Forest, Andhra Pradesh, India
– A.J. Solomon Raju, Pp. 14923–14926