

## Acknowledgements

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**Vinciane Fack**, Université Libre de Bruxelles, Faculté des Sciences, Service d'Anthropologie et Génétique humaine CP.192, Brussels, Belgium, Asociación Neotropical Primate Conservation Peru, La Esperanza, Yambrasbamba, Amazonas, Peru and, Centre de Primatologie de l'Université de Strasbourg, France, E-mail: <vinciane.fack@gmail.com>, **Sam Shanee**, Asociación Neotropical Primate Conservation Peru, La Esperanza, Yambrasbamba, Amazonas, Peru and Neotropical Primate Conservation, Seaton, Cornwall, United Kingdom, **Régine Vercauteren Drubbel**, Université Libre de Bruxelles, Faculté des Sciences, Service d'Anthropologie et Génétique humaine CP.192, Brussels, Belgium, **Hélène Meunier**, Centre de Primatologie de l'Université de Strasbourg, France and Laboratoire de Neurosciences Cognitives et Adaptatives, UMR 7364, CNRS et Université de Strasbourg, France, and, **Martine Vercauteren**, Université Libre de Bruxelles, Faculté des Sciences, Service d'Anthropologie et Génétique humaine CP.192, Brussels, Belgium.

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## DIFFERENCES IN THE PREVALENCE OF CUTANEOUS MYIASIS BETWEEN *AOTUS VOCIFERANS* AND *AOTUS NANCYMAE* IN THE COLOMBIAN AMAZON

Néstor Roncancio  
 María Alejandra Santa  
 Liza María Calderón  
 Edith Natalia Gómez  
 Amilvia Acosta  
 Lina Marcela García  
 Beatriz Eugenia Henao  
 Sandra Milena Peñuela  
 Erick Alexander Pinilla  
 Robin Andrés Poches  
 Erika Rodríguez

## Introduction

Parasites are part of the natural processes allowing for the regulation of populations and the balance of the ecosystems (Clayton and Moore, 1997; Delahay et al., 2009). Parasites can affect population parameters such as birth and death rates (Nunn and Altizer, 2006; Delahay et al., 2009) and some mathematical models even suggest that they could play an important role in the host's population and evolutionary dynamics (Begon et al., 2009; Nunn et al., 2011). However, the specific role of infectious diseases in population and evolutionary dynamics and details of that interaction, remains one of the biggest unanswered questions in ecology (McCallum, 2000; Delahay et al., 2009).

Epidemiological surveillance (monitoring of the distribution, prevalence and incidence of diseases) allows the evaluation of host populations and environmental parameters and is also used in the monitoring, control, and prevention of diseases (Morner et al., 2002). From a public health perspective, primates are an important group for epidemiological surveillance due to the impact that diseases can have on their endangered populations, and also because the risk of zoonotic transmission. As some primate species are used for bush meat, biomedical models or, as pets, primates are in continuous close contact with humans, which increases the risk of cross-transmission and disease spread, highlighting the urgent need of primate epidemiological surveillance (Chapman et al., 2005). The epidemiological surveillance in primates is both noticeably lacking and inconsistent, especially in developing countries and it has been estimated that there are between 29% and 40% more species of parasites than the ones currently reported (Cooper and Nunn, 2013). Additionally, parasitic infections in primate species with nocturnal behavior have been studied even more infrequently. Specifically, only 38 parasitological studies on the genus *Aotus* has been reported, in which 12 species

of parasites were found (Cooper and Nunn, 2013). This study highlights an important parasite affecting nocturnal primates in an attempt to fill out this research gap.

During a survey of night monkeys (genus *Aotus*) in the Colombian Amazon (Bloor et al., 2014), we collected data on the presence of ectoparasites, particularly cutaneous myiasis. This disease refers to the infestation with dipterous (flies) larvae that feed on living or necrotic tissue (Hall and Wall, 1995). In this study, we present a comparison of the prevalence of cutaneous myiasis between *Aotus vociferans* and *Aotus nancymae* in adjacent populations in the Colombian Amazon.

## Materials and methods

### Study area

This study was carried out between July and November of 2012 in the forest area of the municipality of Puerto Nariño, department of Amazonas (Colombia). We collected the data from nearby indigenous communities including Doce de Octubre (-70°30'15"W, -3°44'10"S), Naranjales (-70°31'47"W, -3°52'18"S), San Juan de Atacuari (-70°39'34"W, -3°49'26"S), Santa Clara de Tarapoto (-70°24'51"W, -3°48'02"S) and San Pedro de Tipisca (-70°35'36"W, -3°41'12"S). The first four sites are in the flooded plain of the Amazon River, while San Pedro de Tipisca is located in the "Terra firme" dry zone of the Loretoyacu River (Fig. 1).

### Data collection

Samples were collected from live-caught individuals. These captures were done by a research team consisting of a biologist, a veterinarian, and some local experts. The local experts used certified tree-climbing equipment for their security and received from six to twelve hours of training in tree climbing techniques. To perform captures, the local experts first

followed the primates from 03:00 to 06:30 hours. After confirming the presence of monkeys in a hole in a tree, the team carried out the captures between 09:30 and 15:00 hours, the period when the monkeys are asleep. After the hole was covered, the animals were extracted, put in dark bags, and examined by the veterinarian. The animals were weighed and then sedated with ketamine (5%) with doses between 5 to 15 mg/kg of weight, intramuscular. The duration of sedation was approximately 35 minutes and the time of recovery was approximately 90 minutes. The vitals for each animal were monitored continuously assessing temperature and cardiac and respiratory frequency, while the presence of cutaneous myiasis was recorded. The animals were tattooed on the thigh with a numeric code and released after their recovery.

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### Data analyses

We estimated the prevalence of cutaneous myiasis of both species with Bayesian methods using an uninformative *a priori* binomial distribution (between 0 and 100%) and assuming that the posterior distributions were fitted to the uniform distribution (McCarthy, 2007; Pfeiffer et al., 2008). Prevalence estimation was done with Markov chains with 100,000 iterations after a burn-in of 10,000 iterations for the final estimation, all using OpenBugs 3.2.2 software (Lunn-D et al., 2000). To compare the prevalence of the cutaneous myiasis between the two species, we used probability intervals (PI) graphics. When both PI showed over a 25% overlap, we assumed that there was no significant difference in the prevalence at 95% confidence level (Cumming et al., 2007).

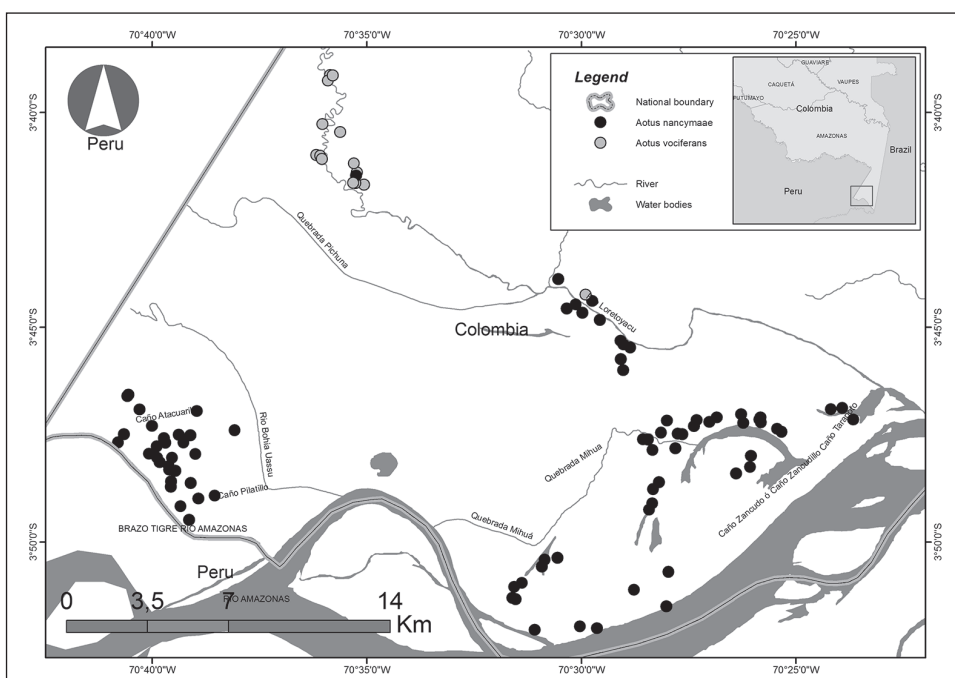


Figure 1. Site of study in the Colombian-Peruvian boundary.

## Results

We captured 150 individuals of *A. nancymaae* and 19 individuals of *A. vociferans* (Bloor et al., 2014). Five *A. vociferans* and one *A. nancymaae* died during the capture. Cutaneous myiasis was found in three *A. vociferans* individuals: two juvenile males with one and four larvae respectively, and one lactating female with nine larvae. The larvae length was 1.5-2.5 cm and the skin lesion was furuncular

(Fig. 2). For *A. nancymaae* we found scar lesions generated by cutaneous myiasis in one individual; and we recorded those lesions as a positive case (in order to avoid type II error related to the hypothesis that the disease affects this species in this site). The prevalence of infection in both species was 19% (PI 95% = 6 – 38) for *A. vociferans* and 1.3% (PI 95% = 0.2 – 3.6) for *A. nancymaae*. The difference in the prevalence of cutaneous myiasis between both species was statistically significantly (Fig. 3).

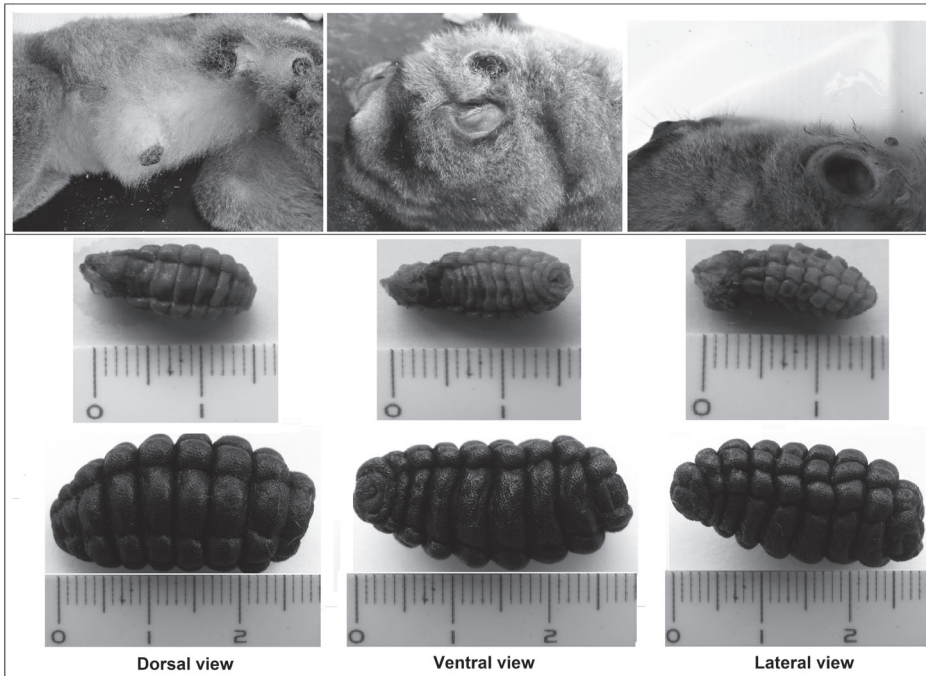


Figure 2. Lesions and some specimens of parasites recorded in sampled night monkeys (*Aotus vociferans*).

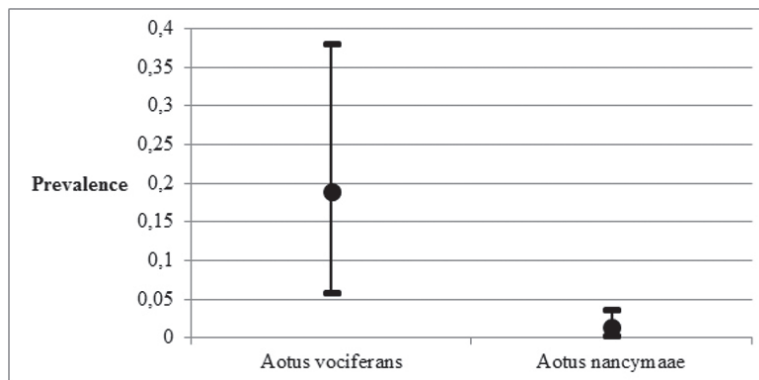


Figure 3. Probability Intervals comparison of the prevalence of cutaneous myiasis between *Aotus vociferans* and *A. nancymaae*.

## Discussion

We found evidence of infestation by cutaneous myiasis in both species of night monkey, with a significantly lower prevalence in *A. nancymaae* (1.3%) compared to *A. vociferans* (19%), in spite of being adjacent populations. Cutaneous myiasis can be found in Neotropical primates, specifically howler monkeys. *Cuterebra baeri* is the main etiological

agent and likely is involved in a species-specific relationship with howler monkeys (Zeledón-Araya et al., 1957; Milton, 1996; Stuart et al., 1998; de Thoisy et al., 2001; Olger Calderón-Arguedas, 2004; Arroyo-Rodríguez et al., 2008; Colwell, 2008; Cristobal-Azkarate et al., 2012; Trevez and Carlson, 2012; Guimaraes, 1971). In the case of *Aotus* sp., the same etiological agent for cutaneous myiasis was found in Brazil, likely through accidental infection (Guimaraes,

1971). In our study, the prevalences are lower compared to the ones found in howler monkeys, which are between 28.6% and 76 % (Milton, 1996; Calderón-Arguedas, 2004; Cristobal-Azkarate et al., 2012; Trevez and Carlson, 2012).

This kind of myiasis commonly generates pathological effects and is found mainly in mammals, although birds, reptiles and amphibians are occasionally hosts of the parasite (Munger and Karasov, 1994). Pathological effects vary depending on the parasite species, number of larvae, and the site of the infestation (Munger and Karasov, 1994) and include irritation, pruritus, weight loss, fertility reduction, death by tissue damage, secondary bacterial infection, dehydration, haemorrhage, anaphylaxis, and toxemia (Wall and Shearer, 1997). In howler monkeys in Costa Rica, a correlation between the incidence of infestation and mortality was found (Milton, 1996). In the present study, the juvenile male that we captured had four larvae and was easily captured due to its weakness; it also did not survive the manipulation. Necropsy revealed extremely poor body condition, anaemia and dehydration. Likewise, the lactating female found with nine larvae had a low weight (600 g), similar to the juvenile individuals (mean weight of 635g).

The difference in the prevalence of cutaneous myiasis between these two species in adjacent and overlapping habitats, suggests the existence of different risk factors. These risks could vary with habitat preferences of the primate (Aquino and Encarnación 1988) or the parasite species and the differences in the susceptibility to disease of each primate. For example, a difference in mortality rate was found between *A. nancymae* and *A. vociferans* in captive populations (Gozalo and Montoya, 1990). However, data analyzed in the same laboratory between 1988 and 2002 show a similar mortality rate in both species (75% in *A. nancymae* and 77% in *A. vociferans*) by similar causes, mainly pneumonia and gastrointestinal diseases (Sánchez et al., 2006). Thus, it is necessary to increase the sampling effort of natural populations, in order to identify the habitat preferences and distribution of both species in this region, and to evaluate the association between habitat and parasite prevalence and how this can affect population dynamics (Janson, 2011).

The explicit taxonomic determination of larvae species was not possible in this study without the collection and further analysis of the specimens. However, the morphological characteristics of the larvae are similar to *Cuterebra baeri*. In general, the identification is low in similar studies (Colwell and Milton, 1998; Calderón-Arguedas, 2004). It is necessary to increase the effort to identify the species since the epidemiology and the effect on the host could vary significantly depending on the parasite species (Cristobal-Azkarate et al., 2012).

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**Néstor Roncancio**, Instituto Amazónico de Investigaciones Científicas – Sinchi, E-mail: <nroncancio@gmail.com>, **María Alejandra Santa**, Instituto de Genética, Universidad Nacional de Colombia, **Liza María Calderón**, **Edith Natalia Gómez**, **Amilvia Acosta**, **Lina Marcela García**, **Beatriz Eugenia Henao**, Instituto Amazónico de Investigaciones Científicas – Sinchi, **Sandra Milena Peñuela**, **Erick Alexander Pinilla**, **Robin Andrés Poches** and **Erika Rodríguez**, Instituto de Genética, Universidad Nacional de Colombia.

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