Acknowledgements

We wish to thank Noga Shanee, Nestor Allgas and the members of Neotropical Primate Conservation Peru for supporting this study and for helping us with research design and species identification. We also thank the many local research assistants. This work is part of a study funded by Neotropical Primate Conservation, the Fonds National de La Recherche Scientifique (FNRS) and the Fonds Léopold III pour l'Exploration et la Conservation de la Nature and conducted under permit number 173-2016-SERFOR/DGGSPFFS given by the Servicio Forestal of Peru.

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**, Asociacion 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.

References

Alves-Costa, C. P., da Fonseca, G. A. B. and Faro, C. C. 2004. Variation in the diet of the brown-nosed coati (*Nasua nasua*) in Southeastern Brazil. *J. Mammal.* 85(3): 478–482.

Beisiegel, B.M. 2001. Notes on the coati, *Nasua nasua* (Carnivora: Procyonidae) in an Atlantic forest area. *Braz. J. Biol.* 61(4): 689–692.

de Resende, B. D., Mannu, M., Izar, P. and Ottoni, E. B. 2004. Interaction between capuchins and coatis: Nonagonistic behaviors and lack of predation. *Int. J. Primatol.* 25(6): 1213–1224.

Haugaasen, T. and Peres, C. A. 2008. Associations between primates and other mammals in a central Amazonian forest landscape. *Primates.* 49: 219–222.

Shanee, S. 2014. Ranging Behavior, Daily Path Lengths, Diet and habitat use of Yellow Tailed Woolly Monkeys (*Oreonax flavicauda*) at La Esperanza, Peru. In: Defler, T. R., Stevenson, P. R. (eds) The Woolly Monkey: Behavior, Ecology, Systematics and Captive Research. Springer, New York, pp 169–187.

Shanee, S. and Shanee, N. 2015. Measuring success in a community conservation project: local population increase in a critically endangered primate, the yellow-tailed woolly monkey (*Lagothrix flavicauda*) at la Esperanza, northeastern Peru. *Trop. Conserv. Sci.* 8(1): 169–186.

DIFFERENCES IN THE PREVALENCE OF CUTANEOUS MYIASIS BETWEEN *AOTUS VOCIFERANS* AND *AOTUS NANCYMAAE* 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 nancymaae* 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 (-70º30'15"W, -3º44'10"S), Naranjales (-70º31'47"W, -3º52'18"S), San Juan de Atacuari (-70º39'34"W, -3º49'26"S), Santa Clara de Tarapoto (-70º24'51"W, -3º48'02"S) and San Pedro de Tipisca (-70º35'36"W, -3º41`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.

This study was carried out under the agreement 10F of environmental authorities (Ministry of the Environment and CorpoAmazonia), supported by the National University and Instituto Sinchi (Amazon Research Institute of Colombia), all of them, part of the SINA (National Environmental System).

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 Marcov 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).

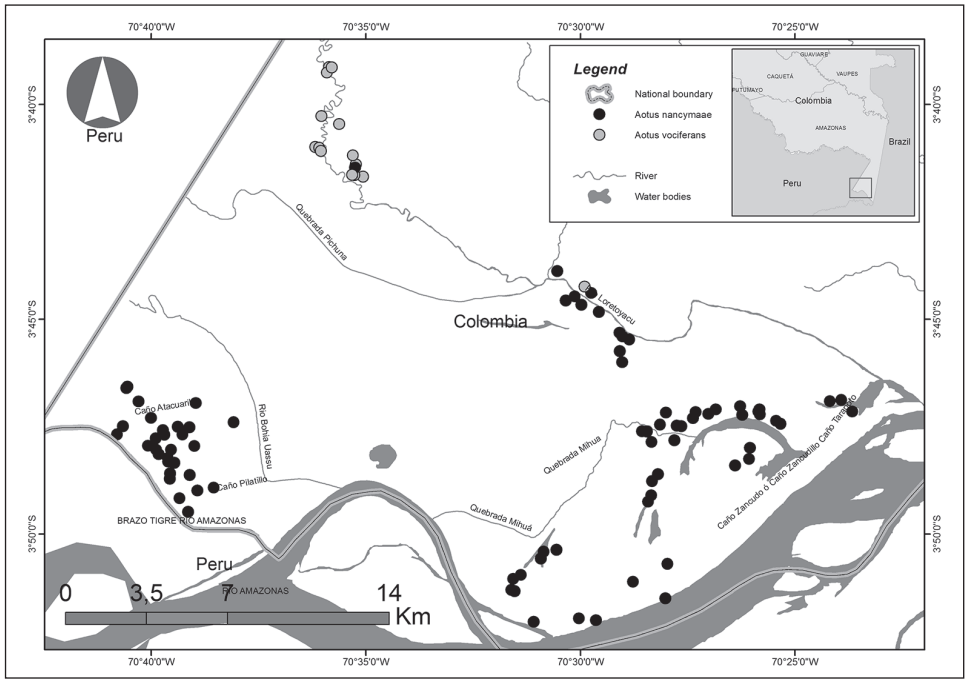

Figure 1. Site of study in the Colombian-Peruvian boundary.

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).

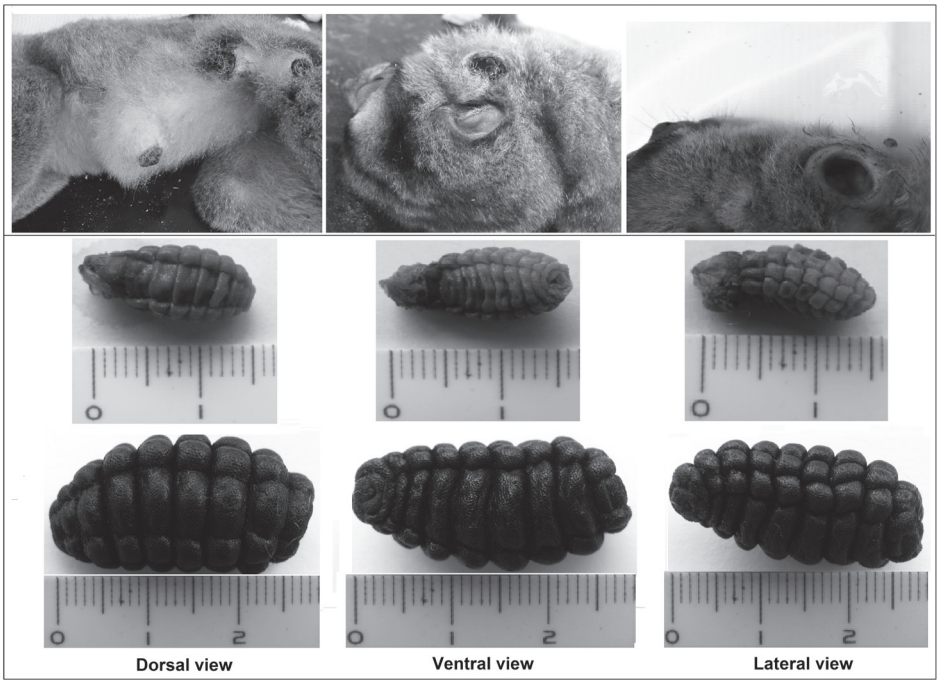

Figure 2. Lesions and some specimens of parasites recorded in sampled night monkeys (*Aotus vociferans*).

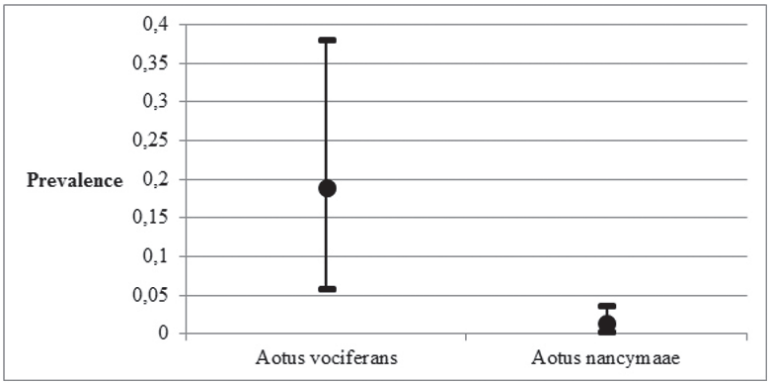

Figure 3. Probability Intervals comparison of the prevalence of cutaneous myiasis between *Aotus vociferans* and *A. nancymaae*.

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 toxaemia (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. nancymaae* 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. nancymaae* 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).

Acknowledgements

This study was done with the financial and technical support of Instituto Sinchi, Instituto de Genética de la Universidad Nacional de Colombia and the Corporación Autónoma Regional de la Amazonia, CORPOAMAZONIA. The fieldwork was successfully done thanks to the TICOYA indigenous communities and their local experts.

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.

References

Aquino, R. and F. Encarnación. 1988. Population densities and geographic distribution of night monkeys (*Aotus nancymai* and *Aotus vociferans*) (Cebidae: Primates) in northeastern Peru. *Am. J. Primatol*. 14: 375–381.

Arroyo-Rodríguez, V., Asensio, N. and Cristóbal-Azkarate, J. 2008. Demography, life history and migrations in a Mexican mantled howler group in a rainforest fragment. *Am. J. Primatol.* 70(2): 114–118.

Begon, M., Townsend, C. R. and Harper, J. L. 2009. Ecology: From Individuals to Ecosystems. Blackwell publishing. Malden, MA, USA, 752pp.

Bloor, P., Ibañez, C., Arciniegas, S., Hoyas, M. and Hernández, S. 2014. Estudio genético del género *Aotus* al sur de la Amazonia de Colombia. Asociacio´n Colombiana de Zoologi´a. 2015. La biodiversidad sensible: patrimonio natural irreemplazable. IV Congreso Colombiano de Zoologi´a. Libro de resu´menes. Asociacio´n Colombiana de Zoologi´a. Disponible en li´nea: www.congresocolombianodezoologia.org /www.aczcolombia.org.

Calderón-Arguedas, O. and Troyo, A. 2004. Infección por larvas de *Alouattamyia baeri* (Diptera: Cuterebridae) en monos aulladores, *Alouatta palliata* (Primates: Cebidae) de la costa Caribe de Costa Rica. *Neotrop*. *Primates* 12: 21–24.

Chapman, C. A., Gillespie, T. R. and Goldberg, T. L. 2005. Primates and the ecology of their infectious diseases: How will anthropogenic change affect host-parasite interactions? *Evol*. *Anthropol*. 14(4): 134–144.

Clayton, D. H. and Moore, J. 1997. Host-Parasite Evolution: General Principles and Avian Models. Oxford University Press. Oxford, UK, 473pp.

Colwell, D. D. 2008. Bot Flies and Warble Flies (Order Diptera: Family Oestridae). In: Parasitic Diseases of Wild Mammals. Samuel, W. M., Pybus, M. J., Kocan, A. A, editors. State University Press, Ames, Iowa, pp. 46–71.

Cooper, N. and Nunn, C. H. 2013. Identifying future zoonotic disease threats: Where are the gaps in our understanding of primate infectious diseases? Evol. Med. Public Health 1:27-36.

Cristobal-Azkarate, J., Colwell, D. D., Kenny, D., Solórzano, B., Shedden, A., Cassaigne, I. and Luna, E. R. 2012. First report of bot fly (*Cuterebra baeri*) infestation in howler monkeys (*Alouatta Palliata*) from Mexico. *J. Wildl. Dis*. 48(3): 822–825.

Cumming, G., Fidler, F., and Vaux, D. L. 2007. Error bars in experimental biology. *J. Cell Biol*. 177(1): 7–11.

Colwell, D. D. and Milton, K. 1998. Development of *Alouattamyia Baeri* (Diptera: Oestridae) from howler monkeys (Primates: Cebidae) on Barro Colorado Island, Panama. *J. Med. Entomol*. 35(5): 674–80.

Delahay, R. J., Smith, G. C. and Hutchings, M. R. 2009. Management of Disease in Wild Mammals. Springer. Tokyo, Berlin, Heidelberg, New York, 284pp.

Gozalo, A. and Montoya, E. 1990. Mortality causes of owl monkeys (*Aotus nancymae* and *Aotus vociferans*) in captivity. *J. Med. Primatol*. 19(1): 69–72.

Guillespie, T. and Chapman, C. A. 2008. Forest fragmentation, the decline of an endangered primate, and changes in host–parasite interactions relative to an unfragmented forest. *Am. J. Primatol*. 70: 222–230.

Guimarães, J. 1971. Notes on the hosts of Neotropical Cuterebrini (*Diptera, Cuterebridae*), with new records from Brazil. *Pap. Avulsos de Zool*. 25: 89–94.

Hall, M. J. R and Wall, R. 1995. Myiasis of Humans and Domestic Animals. *Adv. Parasitol*. 5: 257–334.

Janson, C. H. 2011. Reconciling rigor and range: observations, experiments, and cuasiexperiments in field primatology. *Int. J. Primatol*. 33(3): 520–541.

Lunn, D., Thomas, A., Best, N. and Spiegelhalter, D. 2000. A bayesian modelling framework: concepts, structure, and extensibility. *Stat. Comput*. 10:325–337.

McCallum, H. 2000. Methods in Ecology. Population Parameters: Estimation for Ecological Models. Blackwell Science. Great Britain, 339pp.

McCarthy, M. A. 2007. Bayesian Methods for Ecology. Cambridge University Press. Cambridge, UK, 293pp.

Milton, K. 1996. Effects of bot fly (*Alouattamyia baeri*) parasitism on a free-ranging howler monkey (*Alouatta palliata*) population in Panama. *J. Zool*. 239(1): 39–63.

Morner, T., Obendorf, D. L., Artois, M. and Woodford, M. H. 2002. Surveillance and monitoring of wildlife diseases. *Rev. Sci. Tech*. OIE 21(1): 67–76.

Munger, J. C. and Karasov, W. H. 1994. Costs of bot fly infection in white-footed mice: energy and mass flow. *Can. J. of Zool.* 72(1): 166–173.

Nunn, C. and Altizer, S. 2006. Infectious Diseases in Primates: Behavior, Ecology and Evolution. Oxford University Press. Oxford, UK, 369pp.

Nunn, C. L., Thrall, P. H., Leendertz, F. H. and Boesch, C. 2011. The spread of fecally transmitted parasites in socially-structured populations. PLoS ONE 6(6): e21677.

Pfeiffer, D. U., Robinson, T. P., Stevenson, M., Stevens, K. B., Rogers, D. J. and Clements, A. 2008. Spatial Analysis in Epidemiology. Oxford University Press. New York, 137pp.

Sánchez, N., Gozalo, A., Gálvez, H. and Montoya, E. 2006. Mortalidad en crías de *Aotus* sp. (Primates: Cebidae) en cautiverio: una limitante para estudios biomédicos con modelos animales. Rev. Peru. Med. Exp. Salud Pública 23(3): 221–224.

Stuart, M., Pendergast, V., Rumfelt, S., Pierberg, S., Greenspan, L., Glander, K. and Clarke, M. 1998. Parasites of wild howlers (*Alouatta* spp.). *Int. J. Primatol.* 19(3): 493–512.

Trevez, A. and Carlson, A. 2012. Botfly parasitism and tourism on the endangered black howler monkey of Belize. *J. Med. Primatol*. 41: 284–287.

De Thoisy, B., Vogel, I., Reynes, J. M., Pouliquen, J. F., Carme, B., and Vié, J. C. 2001. Health Evaluation of translocated free-ranging primates in French Guiana. *Am. J. Primatol.* 54(1): 1–16.

Wall, R. and Shearer, D. 1997. Veterinary Entomology: Arthropod Ectoparasites of Veterinary Importance. Chapman & Hall. London, 456pp.

Zeledón-Araya, R., Jiménez-Quirós, O. and Brenes-Madrigal, R. 1957. *Cuterebra baeri* Shannon y Greene, 1926 en el mono aullador de Costa Rica. *Rev. Biol. Trop*. 5(2):129–134.