Notes and records

Colobus monkey parasite infections in wet and dry habitats: implications for climate change

Colin A. Chapman[1,2]*, Michaela L. Speirs[3], Stacey A.M. Hodder[4] and Jessica M. Rothman[5,6]

[1]*Department of Anthropology and McGill School of Environment, McGill University, Montreal, Quebec, Canada H3A 2T7*, [2]*Wildlife Conservation Society, Bronx, NY, U.S.A.*, [3]*College of Public Health & Health Professions, University of Florida, Gainesville, FL, U.S.A.*, [4]*Department of Anthropology, McGill University, Montreal, Quebec, Canada, H3A 2T7*, [5]*McGill School of Environment, McGill University, Montreal, Quebec, Canada and* [6]*Department of Anthropology, Hunter College of the City University of New York, New York, NY, U.S.A.*

Introduction

The earth's climate has warmed by ∼0.6°C over the past 100 years and some estimates suggest that the climate could warm by 5.8°C this century (IPCC, 2001; Walther *et al.*, 2002). Today, with many animal populations isolated in protected areas or being limited to high elevations, their flexibility to respond to climate change by shifting their range is limited (Dunbar, 1998; Mcclean *et al.*, 2005; Chapman, Lawes & Eeley, 2006a). Although it is important to identify the changes in animal populations caused by climate change that are most obvious, like loss of habitat, it is also essential to recognize the subtle or cascading changes that may also affect populations. Such changes may have just as substantial an impact on animal populations as the apparent impacts of climate change (Lovett, Midgley & Barnard, 2005). One potential effect of climate change may be an alteration of host–parasite dynamics.

In the human medical literature, connections between climate and disease are well established, with specific diseases occurring during certain seasons or in association with specific unseasonable conditions. For example, in sub-Saharan Africa, meningococcal meningitis epidemics occur during the hot dry season (Patz *et al.*, 1996). Similarly, in the United States, 68% of waterborne disease outbreaks, such as *Giardia* and *Cryptosporidium*, are preceded by heavy rain events (Hunter, 2003).

The objective of this study was to use small-scale spatial variation in climate to investigate whether such variation corresponds to differences in disease dynamics. We studied how indices of gastrointestinal parasite infections of black-and-white colobus (*Colobus guereza*) monkey groups in Kibale National Park, Uganda varied as a function of whether the group inhabited wet or dry habitats. At one site (Kanyawara), we sampled five groups that frequented swampy lowlands and nine groups that ranged in drier uplands. Subsequently, we compared the same upland groups at Kanyawara to upland groups that were 30 km south in a region receiving 361 mm rainfall less each year (Mainaro). We predicted that groups in the wetter habitats would exhibit elevated gastrointestinal parasite infections relative to groups in drier areas (i.e., elevated prevalence, abundance and/or species richness). For gastrointestinal parasites this is a reasonable prediction because many of the conditions that promote transmission are influenced by climatic conditions. For example, increased rain is thought to allow parasite eggs and infective stage larvae to persist in the environment longer and thus increase infection risk (Grove, 1989; Gillespie, 2001).

Materials and methods

Kibale National Park, Uganda (0°13′–0°41′ N and 30°19′–30°32′ E) is a moist-evergreen forest receiving approximately 1719 mm of rainfall annually (1990–2006), but it receives ∼300 mm more rainfall/year than it did at the start of the twentieth century (Fig. 1). Other climatic changes include less frequent droughts, an earlier onset of the rains and an increase of just over 4°C in average maximum monthly temperature over 33 years (Fig. 1). These changes are much higher than global averages (IPCC, 2001; see Altmann, Alberts & Roy, 2002; for a similar example from East Africa). The study took place at two comparably forested sites: Kanyawara (1500 m; rainfall 1712 mm) and Mainaro (1394 m; rainfall 1351 mm).
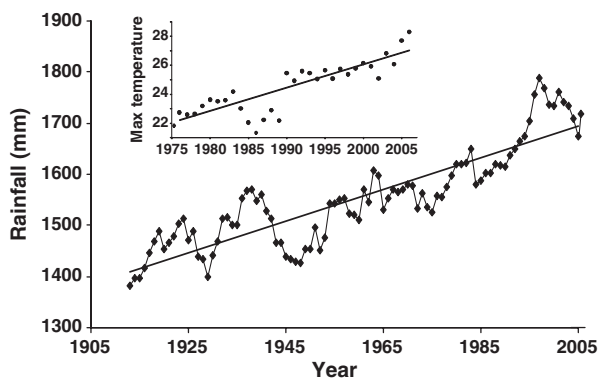
Correspondence: E-mail: colin.chapman@mcgill.ca

Fig 1 The 10 year running average of the annual rainfall in the area of Kibale National Park, Uganda and an inlay of the average monthly temperature since 1975.

Kanyawara is 30 km north of Mainaro and receives 361 mm more rain. Sites were selected to minimize potentially confounding variables that could influence parasite infections. The upland and lowland sites at Kanyawara were in close proximity, thus differences in forest composition were minimal and limited to the abundance of trees specializing in swamps. With respect to Kanyawara and Mainaro, while the species compositions of these forests differed, the species richness of the tree community was similar, as was the average size of the trees (Chapman *et al.*, 1997). With the exception that *Cercopithecus mitis* was absent from Mainaro, primate densities at the sites were roughly similar (Chapman & Lambert, 2000).

At Kanyawara, we collected faecal samples from groups that frequented wet lowland areas (56 samples from five groups) and groups that were only found on the drier uplands (73 samples from nine groups), while at Mainaro we collected only from upland groups (67 samples from ten groups). All samples were collected in May and June of 2005 and 2006 to minimize seasonal effects. Black-and-white colobus have small home ranges (6.7–32.8 ha; Harris & Chapman, 2007); thus, it is unlikely that the colobus from the wet area at Kanyawara traveled to the dry area or vice versa. Faecal samples for parasite analysis were stored in 10% formalin and processed using concentration by sodium nitrate flotation. Parasite eggs and larvae were counted and identified on the basis of egg color, shape, contents and size.

The parasite community described from Kanyawara included the following nematodes: *Trichuris* sp. (Superfamily Trichuroidea), a strongyle that we believe to be

Oesophagostomum sp. (Superfamily Strongyloidea), and an unidentified strongyle. We also identified two protozoans, likely *Entamoeba coli* and *E. histolytica/dispar*. *E. histolytica* and *E. dispar* have cysts that are morphologically indistinguishable; and it was only recently that *E. dispar* was considered a distinct species (Gatti *et al.*, 2002). However, *E. histolytica* is pathogenic, while *E. dispar* is not. Due to the small sample size of the unidentified strongyle and *Entamoeba coli* and *E. histolytica/dispar*, these species were not contrasted among habitats. At Mainaro, we identified *Trichuris* sp. and an unidentified strongyle, but not *Oesophagostomum* sp. The unidentified strongyle and *Entamoeba* were included in the calculation of species richness.

At each of the collection locations we attempted to get one sample from each individual in the group excluding infants; however since individuals were not individually identifiable it was possible that some female could have been sampled more than once. The groups typically have only one adult male, and if not they were identifiable, thus we are relatively confident that males were not repeatedly sampled. Subsequently, we took the average for the group for each indices of parasite infection and contrasted populations using Mann–Whitney tests using the group mean as the unit of comparison.

Results and discussion

Parasite abundance was higher for *Trichuris* sp. infections in the wet lowlands than the dry highlands of Kanyawara (*Trichuris* sp. $U = 8.00$, $P = 0.027$; lowland mean = 95.4, highland mean = 41.8) and there was a tendency for the abundance of *Oesophagostomum* sp. to be higher in the lowland as well (*Oesophagostomum* sp. $U = 15.00$, $P = 0.0.082$, lowland mean = 0.044, highland mean = 0.008). The prevalence of *Trichuris* sp. and *Oesophagostomum* sp. did not differ between the lowland and upland sites (*Trichuris* sp. $U = 18.00$, $P = 0.090$; *Oesophagostomum* sp. $U = 15.00$, $P = 0.080$). As predicted, the richness of the parasite community in groups in the wet lowlands at Kanyawara was higher than that of groups in the dry upland (Mann–Whitney $U = 3.50$, $P = 0.005$; swamp = 1.40; upland 1.07 species).

At the drier Mainaro site, we identified *Trichuris* sp. and an unidentified strongyle, but not *Oesophagostomum* sp. The abundance of *Trichuris* sp. was higher at the wet site (mean = 41.8) when compared to the drier Mainaro site (mean = 18.33, $U = 9.0$, $P = 0.002$). As predicted, the prevalence of *Trichuris* sp., was higher at the wet site

(mean = 100) than at the drier site (mean = 79.35, $U = 22.50$, $P = 0.009$). The richness of the parasite community in groups in the wet Kanyawara upland site was higher than that of groups in the dry Mainaro site ($U = 15.00$, $P = 0.024$), but the biological importance of this difference is questionable because richness in both populations is low (Kanyawara upland = 1.07, Mainaro upland = 1.01 species).

We documented that colobus groups that frequented wetter areas showed elevated indices of parasite infections as compared to groups in drier areas or regions (see also Stoner, 1996). While some argue that gastrointestinal parasites have little impact on host populations (Munger & Karasov, 1989), others present evidence of biologically significant impacts, particularly when the host population is nutritionally stressed (Coop & Holmes, 1996; Chapman *et al.*, 2006b).

The population effects of such changes in parasite infections remain to be evaluated for these monkeys. However, since a 32-year record of plant phenological patterns suggests that climate change in this region has led to periods of food scarcity causing nutritional stress in primates (Chapman *et al.*, 2005), and since stress has been shown to increase the biological significance of parasite infections in colobus monkeys (Chapman *et al.*, 2006b), the impact of climate change on host–parasite interactions should receive more detailed study. This study has a limited sample size, could not control for ecological factors like group size, and represents a pseudoreplicated design within one park, thus it should be interpreted with caution. However, the findings do suggest that interactions between climate and parasitism deserve more attention.

Acknowledgements

References

ALTMANN, J., ALBERTS, S.C. & ROY, S.B. (2002) Dramatic change in local climate patterns in Amboseli basin, Kenya. *Afr. J. Ecol.* **40**, 248–251.

CHAPMAN, C.A. & LAMBERT, J.E. (2000) Habitat alteration and the conservation of African primates: case study of Kibale National Park, Uganda. *Am. J. Primatol.* **50**, 169–185.

CHAPMAN, C.A., CHAPMAN, L.J., WRANGHAM, R., ISABIRYE-BASUTA, G. & BEN-DAVID, K. (1997) Spatial and temporal variability in the structure of a tropical forest. *Afr. J. Ecol.* **35**, 287–302.

CHAPMAN, C.A., CHAPMAN, L.J., STRUHSAKER, T.T., ZANNE, A.E., CLARK, C.J. & POULSEN, J.R. (2005) A long-term evaluation of fruiting phenology: importance of climate change. *J. Trop. Ecol.*, **21**, 31–45.

CHAPMAN, C.A., LAWES, M.J. & EELEY, H.A.C. (2006a) What hope for African primate diversity? *Afr. J. Ecol.* **44**, 1–18.

CHAPMAN, C.A., WASSERMAN, M.D., GILLESPIE, T.R., SPEIRS, M.L., LAWES, M.J., SAJ, T.L. & ZIEGLER, T.E. (2006b) Do nutrition, parasitism, and stress have synergistic effects on red colobus populations living in forest fragments? *Am. J. Phys. Anthropol.* **131**, 525–534.

COOP, R.L. & HOLMES, P.H. (1996) Nutrition and parasite interaction. *Int. J. Parasitol.* **26**, 951–962.

DUNBAR, R.I.M. (1998) Impact of global warming on the distribution and survival of the gelada baboon: a modeling approach. *Global Change Biol.* **4**, 293–304.

GATTI, S., SWIERCYNSKI, G., ROBINSON, F., ANSELMI, M., CORRALES, J., MOREIRA, J., MONTALVO, G., BRUNO, A., MASERATI, F., BISOFFI, Z. & SCAGLIA, M. (2002) Amoebic infections due to the *Entamoeba histolytica-Entamoeba dispar* complex: a study of the incidence in a remote rural area of Ecuador. *Am. J. Trop. Med. Hyg.* **67**, 123–127.

GILLESPIE, S.H. (2001) Intestinal nematodes. In: Principles and Practice of Clinical Parasitology (Eds S. H. GILLESPIE and R. D. PEARSON). John Wiley and Sons Ltd, New York.

GROVE, D.I. (1989) Strongyloidiasis: A Major Roundworm Infection of Man. Taylor and Francis, London.

HARRIS, T.R. & CHAPMAN, C.A. (2007) Variation in the diet and ranging behavior of black-and-white colobus monkeys: Implications for theory and conservation. *Primates,* **28**, 208–221.

HUNTER, P.R. (2003) Climate change and waterborne and vector-borne disease. *J. Appl. Microbiol.* **94**, 37S–46S.

IPCC (2001) Climate Change 2001: The Scientific Basis. Cambridge University Press, Cambridge.

LOVETT, J.C., MIDGLEY, G.F. & BARNARD, P. (2005) Climate change and ecology in Africa. *Afr. J. Ecol.* **43**, 163–169.

MCCLEAN, C.J., LOVETT, J.C., KUPER, W., HANNAH, L., SOMMER, J.H., BARTHLOTT, W., TERMANSEN, M., SMITH, G.F., TOKUMINE, S. & TAPLIN, J.R.D. (2005) African plant diversity and climate change. *Ann. Missouri Botanical Gardens,* **92**, 139–152.

MUNGER, J.C. & KARASOV, W.H. (1989) Sublethal parasites and host energy budgets: tapeworm infection in white-footed mice. *Ecology,* **70**, 904–921.

PATZ, J., EPETEIN, P., BURKE, T. & BALBUS, J. (1996) Global climate change and emerging infectious diseases. *J. Am. Med. Assoc.* **275**, 217–223.

STONER, K. (1996) Prevalence and intensity of intestinal parasites in mantled howling monkeys (*Alouatta palliata*) in northeastern Costa Rica: implications for conservation biology. *Conserv. Biol.* **10**, 539–546.

WALTHER, G.R., POST, E., CONVEY, P., MENZEL, A., PARMESAN, C., BEEBEE, T.J.C., FROMENTIN, J.M., HOEGH-GULDBERG, O. & BAIRLEIN, F. (2002) Ecological responses to recent climate change. *Nature* **416**, 389–395.