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Observational Monitoring of Clinical Signs during the Last Stage of Habituation in a Wild Western Gorilla Group at Bai Hokou, Central African Republic

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Health monitoring · Clinical signs · Habituation · Ecotourism · Western gorillas · Great apes

Abstract
Anthropozoonotic disease transmission to great apes is a critical conservation concern, and has raised ethical doubts regarding ape habituation. We monitored over a 3-year period clinical signs within a group of wild western gorillas *(G. gorilla)* undergoing habituation at Bai Hokou, Central African Republic. The majority of observations consisted of singular coughs and sneezes among the gorillas. These were the only clinical signs that significantly and positively increased over the years. No changes in the demography of the study group were observed. While clinical signs are not necessarily indicative of 'disease' or other health-related problems, we discuss how long-term records of clinical signs provide useful information when health monitoring, and the importance of the rigid application of preventive disease transmission protocols.

Introduction

Habituation is a process whereby an animal becomes increasingly tolerant of observers at close range as a result of repeated contacts [Williamson and Feistner, 2011]. Whether for research and/or tourism, it has been suggested that habituation can serve as a useful tool for great ape conservation in regions where human population expansion has resulted in severe encroachment on their range [Archabald and Naugton-Treves, 2001; Adams and Infield, 2003; Macfie and Williamson, 2010].

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However, despite the potential conservation, economic and educational benefits, anthropozoonotic disease transmission to habituated great apes is a critical concern given their Red List status [IUCN, 2011] and susceptibility to human pathogens [Sibley and Ahlquist, 1984; Ruvolo et al., 1994; Butynski, 2001]. Uncontrolled disease outbreaks are known to have detrimental effects on an individual's reproductive success and ultimately population persistence in a number of wildlife species [Caron et al., 2003; Hawkins et al., 2006; Smith et al., 2006; Lachish et al., 2007; Keele et al., 2009; Frick et al., 2010]. In light of such risks, doubts have arisen regarding whether we should habituate great apes at all.

Today, measures to reduce disease transmission at ape habituation sites are an ethical prerequisite [Macfie and Williamson, 2010; Williamson and Feistner, 2011]. In recent years, non-invasive sampling techniques have rapidly advanced and been readily adopted by some of the long-standing ape habituation sites, whereby faeces and urine are collected in the field and screened in a laboratory for specific pathogens [Krief et al., 2005; Leendertz et al., 2006a; Kaur et al., 2008; Köndgen et al., 2010; Leendertz et al., 2010]. However, funding for extensive biological sampling is often limited and requires a logistical framework (e.g. trained staff, a working field laboratory) that is rarely in place when ape habituation sites are first established. In light of such logistical constraints experienced by new sites, long-term records of clinical signs may provide basic yet useful information while monitoring the health of apes.

'Clinical signs' refer to observations that are relevant to a potential medical condition. For instance, many upper and lower respiratory tract infections (e.g. colds, influenza, bronchitis) can show various permutations of externally detectable signs (e.g. coughing, sneezing, laboured breathing, and/or a runny nose [Loudon and Brown, 1967; Monto et al., 2000]). Moreover, numerous species of intestinal worm, bacteria, amoeba, and virus may also give rise to signs of persistent diarrhoea or vomiting [Navaneethan and Giannella, 2008]. In addition to these obvious cues, monitoring each animal's behaviour can provide further signs of emerging health problems, such as lethargy, decreased mobility, persistent scratching, or frequent touching/licking of fresh wounds [Dittus and Ratnayeke, 1989; Hart and Powell, 1990; Hay, 2009]. While indeed not all pathogens cause reliable indicators of infection, nor do clinical signs necessarily imply the existence of a 'disease' (e.g. allergies), their potential value for monitoring ape health, combined with the simplicity and ease through which these data are obtained (systematic and daily observations), justifies why they should be recorded over the long term. Indeed, most medical practitioners use clinical signs to facilitate the speed of a diagnosis, which can then lead to faster treatment if necessary. Moreover, systematic and long-term data on clinical signs may help to establish 'normal' baselines whereby, if surpassed, they can serve as an early warning of symptomatic health problems, and/or identify individuals or situations where biological samples should be taken for thorough analysis.

Due to difficulties in habituating the elusive western gorilla to human observers [Doran-Sheehy et al., 2007], very few data are available on the health of this critically endangered species [IUCN, 2011]. Previous health-related studies have predominantly focused on indirect parasitological analyses of unhabituated groups [Tutin et al., 1991; Landsoud-Soukate et al., 1995; Lilly et al., 2002; Freeman et al., 2004], or visual observations made within a specific habitat such as a single forest clearing [Levréro et al., 2007]. Western gorilla habituation is increasingly being used throughout Central Africa to generate tourism and local employment [Macfie and Williamson, 2010]. As such, more health-related studies on these animals are required. Recently, clinical signs were studied over a 7-month period within a fully-habituated wild western gorilla group that was habituated for the purposes of research and tourism [Masi et al., 2012b]. Interestingly, this study found that clinical signs, such as diarrhoea and occurrence of wounds, were relatively low in gorillas compared to wild chimpanzees, while faecal and urinary infections were high in gorillas [Masi et al., 2012a]. Here we present long-term data on clinical signs observed within the same western gorilla group, over a 3-year period, during the final stage of their habituation. We describe and report the frequencies of different clinical signs observed within the group, and investigate temporal changes in their occurrence in relation to socio-ecological and human-related variables.

Methods

Study Site and Subjects

The Bai Hokou study site (2°51′34″N, 16°28′03″E) covers an area of approximately 50 km^2, and is located within the Dzanga sector (495 km^2) of the Dzanga-Ndoki National Park (1,220 km^2) in southwestern Central African Republic. The national park is buffered by a multiple-use zone: the Dzanga-Sangha Special Dense Forest Reserve (3,359 km^2). The annual dry season spans early December to late February. The 9-month rainy season has approximately 165 mm of rainfall per month, with a slightly drier period around June/July. Temperature ranges on average around 24°C (range: 20.8–29.4°C, Bai Hokou long-term records). The western gorilla population in the 2 park sectors, Dzanga and Ndoki, is estimated between 1.0 and 4.5 individuals/km^2, respectively [Blake, 2005; Todd, unpubl. data]. The largest human settlement in the Reserve is the town of Bayanga (30 km from Bai Hokou, approx. 3,925 habitants [Kamiss, 2006]). Wild gorillas have been studied intermittently at Bai Hokou since the 1980s [reviewed in Hodgkinson, 2009]. Since 1998, a controlled tourism program (Primate Habituation Program) was established for the purpose of viewing habituated gorillas [Blom, 2000].

Data on clinical signs were collected from January 2005 until December 2007 on one group of western gorillas, consisting of: 1 silverback, 3–4 adult females, 0–1 subadults, 2–4 juveniles and 4–6 infants (following age-sex classes in Breuer et al. [2009]). We followed the group on a daily basis and each individual was seen and screened for health daily; however, to ensure interobserver reliability, health observations were recorded only when the authors, C. Cipolletta, or a trained observer were present in the gorilla tracking team. Since 2005, all group members have regularly tolerated human presence up to 10 m, with the majority of individuals coming closer than this [Masi, 2008], and by 2007 up to 7 m [Klailova et al., 2010]. The gorillas first reacted to the arrival of observers by ignoring them on 87% of contacts made in 2005 and 2006, and on 91% of contacts made in 2007 (Bai Hokou long-term data). Tourist visits to the group began in September 2004 and a maximum of 3 tourists were allowed daily for a 1-hour visit. From mid-2005 to the end of 2006, two groups of tourists could visit the gorillas split between the morning and afternoon. In collaboration with the Wildlife Conservation Society Field Veterinary Program, health protocols (including routine health monitoring) designed to reduce the risk of human-gorilla disease transmission were put into effect by C. Cipolletta in 1999, and were improved over time (table 1). This research complied with all WWF-approved ethical regulations, and all government policies of the Central African Republic.

Clinical Signs among the Gorillas

During 614 days of group follows (3,335 h of observation by researchers in which health data were systematically collected), we kept daily records of: (1) the frequency and type of coughs and sneezes observed or heard among the gorillas (e.g. dry, or with phlegm), and (2) diarrhoeal events (stools with runny consistency), describing stool colour, consistency, and context (e.g. if occurring during social interactions). Coughs (or sneezes) occurring within bouts less than 1 min

Table 1. History of health policies enforced at Bai Hokou

Basic health policy for gorilla visits[1]
2000 to present
Sick people are not allowed to visit the gorillas
All humans must remain >7 m away from the gorillas
If someone needs to cough or sneeze, they must cover their entire face with the inside of their shirt and turn away
No defecation or spitting in the forest
Urination must be done away from the gorillas
Additional routine health precautions for staff
1998 to present
Deworming with Vermox
2001
Vaccinations for tetanus, measles, polio and diphtheria
Testing for tuberculosis
Latrine-building in nearby villages
Revised staff guidelines at camp
2007 to present
Filtered water
Rinse bleach
Replacement bedding (fungal growth prevention)
Improved hygiene (antibacterial soap, toilet paper)
Evacuation and isolation plans for sick staff
Deworming with Vermox every 6 months
2010 to present
Annual medical examinations for common disease (tuberculosis, hepatitis, worms, amoeba and malaria)
2012 to present
Repeat vaccinations for tetanus, polio, measles, hepatitis B

[1] Following Homsy [1999].

of each other were defined as a single 'event'. To avoid confusion with choking, cough events that occurred while the gorillas were feeding were excluded from this study (20.6% of all cough records, n = 228). At the gorillas' nest sites, where morning and evening faeces are typically excreted, we checked daily for the presence of diarrhoea within the group. In cases of indirect observation of defecation, stools found within a 10-cm radius of each other at a nest site or along gorilla trails were considered a single 'defecation event' [Todd et al., 2008].

Each gorilla was also visually screened at least every 2 days for signs of: (1) *fresh wounds or infections* (length, width, depth, location, presence of discharge and other signs of injury), (2) *skin and hair conditions* (location, missing hair, swollen areas, and scaly patches), (3) *eye conditions* (colour, cloudiness, swelling, and discharge), and (4) *'other signs'* (mobility, abnormal body weight and appetite, lethargy or any behavioural evidence of physical distress, pain or sickness). We conducted an inventory of all observations made during this study using the number of events per month, at first appearance only.

Finally, we present records of the reproductive output and demography of the study group between 2002 (when we began to identify and observe individual group members regularly) until the end of our study in 2007. Reproduction and mortality were used in our study as a proxy for general welfare of the group.

Table 2. Promax-rotated component loadings of human and socioecological variables onto the three extracted components (structure matrix)

Monthly variables	Principal components		
	socioecology (4.2)	tourist presence (3.55)	habituation (1.48)
Total staff contact[1]	**–0.466**	–0.186	0.290
Total staff visibility[1]	–0.271	**0.653**	**0.872**
Average staff minimum distance[2]	–0.077	**–0.709**	**–0.806**
Tourist contact[1]	0.083	**0.932**	0.284
Number of tourists per month	0.068	**0.895**	0.311
Tourist visibility[1]	–0.068	**0.967**	**0.513**
Human-directed aggression[3]	0.254	0.317	**0.759**
Intergroup gorilla interactions[4]	**0.648**	0.244	0.278
Minimum temperature, °C	0.284	–0.087	**–0.644**
Maximum temperature, °C	**–0.848**	0.081	–0.013
Average rainfall, mm	**0.703**	0.224	0.278
Fruit dietary diversity[5]	**0.814**	–0.042	–0.272
Leaf dietary diversity[5]	**–0.887**	0.065	0.151

Salient loadings (>0.4) are in bold. Eigenvalues for each component are in parentheses.
[1] Total minutes per month.
[2] Average closest distance between any gorilla and a team member during contacts each month, using the following scale: 0–5, 6–10, 11–20, 21–30, and >30 m.
[3] Number of days per month with human-directed aggression.
[4] Total number of intergroup gorilla interactions per month.
[5] Number of species consumed per month; following Doran-Sheehy et al. [2004] and Rogers et al. [2004].

Human Variables

Contact with the gorillas was defined as the amount of time humans spent in proximity to (<50 m) and detectable by any member of the study group, regardless of their visibility. Contact was generally initiated around 7.00 h by a morning team (3 Ba'Aka pygmy trackers and 1 local or expatriate observer), and was taken over by an afternoon team (2 trackers and 1 observer) from midday until 17.00 h.

Following international standards, we made all attempts to remain over 7 m from the gorillas [Homsy, 1999; Williamson and Feistner, 2011]. During each contact, the closest distance reached ('minimum distance') between any gorilla and a team member was recorded using the following scale: 0–5, 6–10, 11–20, 21–30, >30 m. Additionally, we recorded all occurrences of gorilla aggression that was directed towards human observers [for definitions, see Blom et al., 2004].

We categorized human-related variables into two classes related to: (1) *staff*, people who regularly visited the study group (trackers, local assistants, expatriate researchers/volunteers), and (2) *tourists*, overseas, regional and local visitors (table 2). The number of staff and contacts remained relatively constant over time and therefore were excluded as variables in the analysis.

Socioecological Variables

Temperature and rainfall were recorded daily at the field site, and then averaged for each month. Through direct observations and food traces found along the group's trail, we recorded daily all food items consumed by the gorillas at first appearance only. Seasonal changes in diet were monitored monthly by averaging the total number of fruit and leaf species consumed in a given month [Doran-Sheehy et al., 2004; Rogers et al., 2004]. During each contact, we recorded all occurrences of interactions within 500 m between the study group and other units (groups or solitary males). Only interactions clearly perceived by the study group (responding by chest beating, or pausing to listen) were included in the analysis.

Statistical Analyses

Our ability to identify the source of respiratory events was often hampered by dense vegetation despite our close proximity to the gorillas. As a result, for all statistical analyses we present these data in terms of the number of days per month in which respiratory events were observed, which serves as a proxy for examining group-wide changes in their frequency over time. To account for monthly differences in sampling effort, we divided the number of days with respiratory events by the number of days of group follows per month.

We used a PASW 18.0 package to test for temporal changes in the occurrence of clinical signs among the gorillas in relation to socioecological and human-related variables (table 2). We only used months that were sampled for over 14 days. To account for interrelatedness between the predictor variables, we used principal component analysis (PCA) to reduce them down to their essential domains ('components'). We used a promax rotation, which minimized correlations between components. The data set passed Bartlett's test of sphericity ($\chi^2 = 277.16$, d.f. = 78, $p < 0.001$), and had a KMO measure (0.702) close to the recommended limit (KMO = 0.70 [Field, 2009]). We determined the number of components to extract based on the scree plot and Kaiser's criterion of 1.0 [Field, 2009].

To examine the relationship between gorilla respiratory events and each of our PCA components, we performed Pearson correlations between each PCA component and the sneezing and coughing data. All other clinical signs (diarrhoea, wounds, skin/hair, eye, other) occurred too infrequently among the gorillas, and were thus excluded from this analysis. Where indicated, all other relationships between two variables were either examined using Pearson correlations or t tests.

Results

PCA of Human and Socioecological Variables

Three components had eigenvalues over Kaiser's criterion of 1.0, and explained 71.0% of the total variance (table 2). A promax rotation revealed a weak correlation between components (all $r \leq 0.43$), and thus our interpretations of component structure were based on how each of the human and socioecological variables loaded onto each component (table 2).

Each component was identified and characterized by high loadings of variables as follows: C1 = component 1 or *socioecology*: fruit/leaf dietary diversity, rainfall, maximum temperature, and intergroup interactions; C2 = component 2 or *tourist presence*: monthly number of tourists, days with tourist visits and tourist contact and visibility time; C3 = component 3 or *habituation*: minimum distance, human-directed aggression, and visibility.

Human Presence and Proximity with Gorillas

Both tourist presence (C2) and habituation (C3) significantly increased over time (C2: $r = 0.68$, $p < 0.001$, n = 36 months; C3: $r = 0.788$, $p < 0.001$, n = 36 months). Duration of staff-gorilla contacts averaged 207.7 ± 28.6 h each month (range: 155.2–262.9 h; n = 36 months). A total of 784 tourists visited the gorillas from 2005 to 2007, averaging 16.56 ± 9.09 h of tourist-gorilla contact time per month (range: 2.83–36.9 h, n = 32 months).

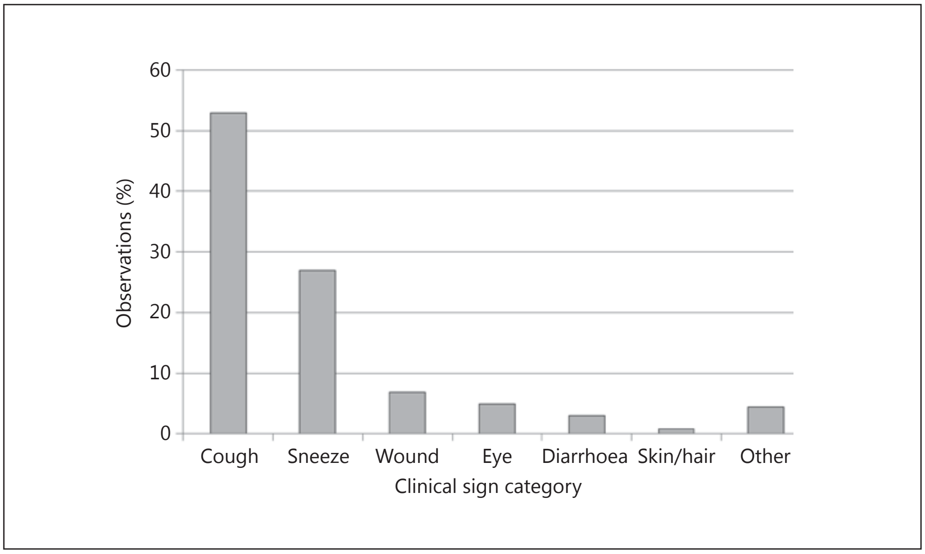

Fig. 1. Percentage of each type of clinical sign accounting for the overall data set of observations recorded in the study group (n = 432).

Clinical Signs among the Gorillas

We recorded 432 clinical signs among the study group. The number of *respiratory events (days with coughing and/or sneezing)* accounted for the majority (80.1% of observations; fig. 1), and were observed on over half of the days we followed the gorillas (56.4% of health observation days). However, there were only 2 independent occasions (observed in an adult female and infant) where an individual showed obvious signs of a respiratory ailment (e.g. productive coughing and consistently runny nose), which disappeared within a few days. Both cases occurred during the peak of the 2007 rainy season, were separated by 2 months, and there was no indication that these same clinical signs had spread to other group members. All other observations of coughing/sneezing appeared to be different from typical symptoms associated with respiratory illness, since they were mostly isolated events with no indication of persistency over time. However, the number of days per month in which respiratory events were recorded significantly increased over time (coughing: $r = 0.461$, $p < 0.01$, $n = 30$ months; sneezing: $r = 0.618$, $p < 0.001$, $n = 30$ months; fig. 2). After excluding the 2 cases in which gorillas displayed signs of a possible respiratory infection, the number of days per month with 'singular' respiratory events still significantly increased over time (coughing: $r = 0.403$, $p < 0.05$, $n = 28$ months; sneezing: $r = 0.618$, $p < 0.001$, $n = 30$ months). Pearson correlations revealed that both habituation and tourist presence correlated significantly with the number of days with sneezing among the gorillas each month, while only habituation was significantly correlated with monthly coughing (statistics are summarized in table 3; fig. 3a, b).

Wound, eye, diarrhoea and skin/hair conditions accounted for relatively few of the observations (fig. 1). *Wounds* (6.9% of health events) consisted of bites or minor

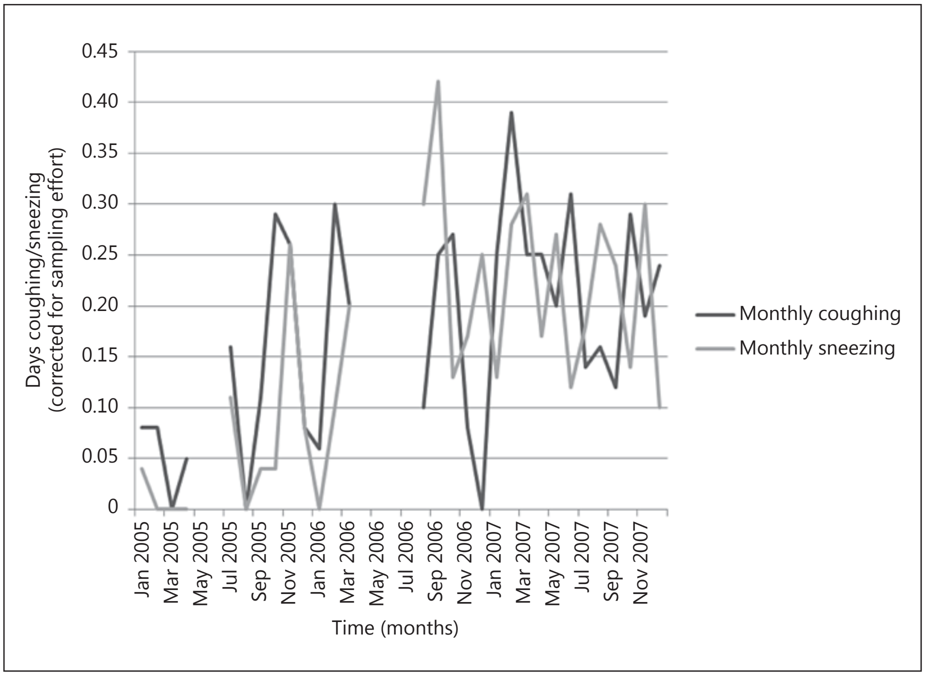

Fig. 2. Temporal changes in the monthly number of days with gorilla coughing and sneezing. Monthly sneezing and coughing are corrected for the number of days in which observations were recorded within the group.

Table 3. Pearson correlation matrix between monthly number of days with gorilla coughing/sneezing and monthly scores on socioecology, tourist presence, and habituation components (n = 30 months)

	Socioecology		Tourist presence		Habituation	
	r	p	r	p	r	p
Coughing	–0.164	0.387	0.329	0.076	0.435	0.016
Sneezing	0.001	0.996	0.445	0.014	0.47	0.009

cuts resulting from falls from trees, inter- and intragroup aggression, or accidents while fleeing from elephants. There was generally little variability in wounds between months (range: 0–3 wounds/month), but nearly twice as many wounds were recorded in 2007 (n = 15) compared to the number recorded in 2005 (n = 6) and 2006 (n = 5).

Of the total number of observations involving *eye problems* (4.9% of health events), 9 of the 21 cases concerned ticks around the gorillas' eyes, which appeared to

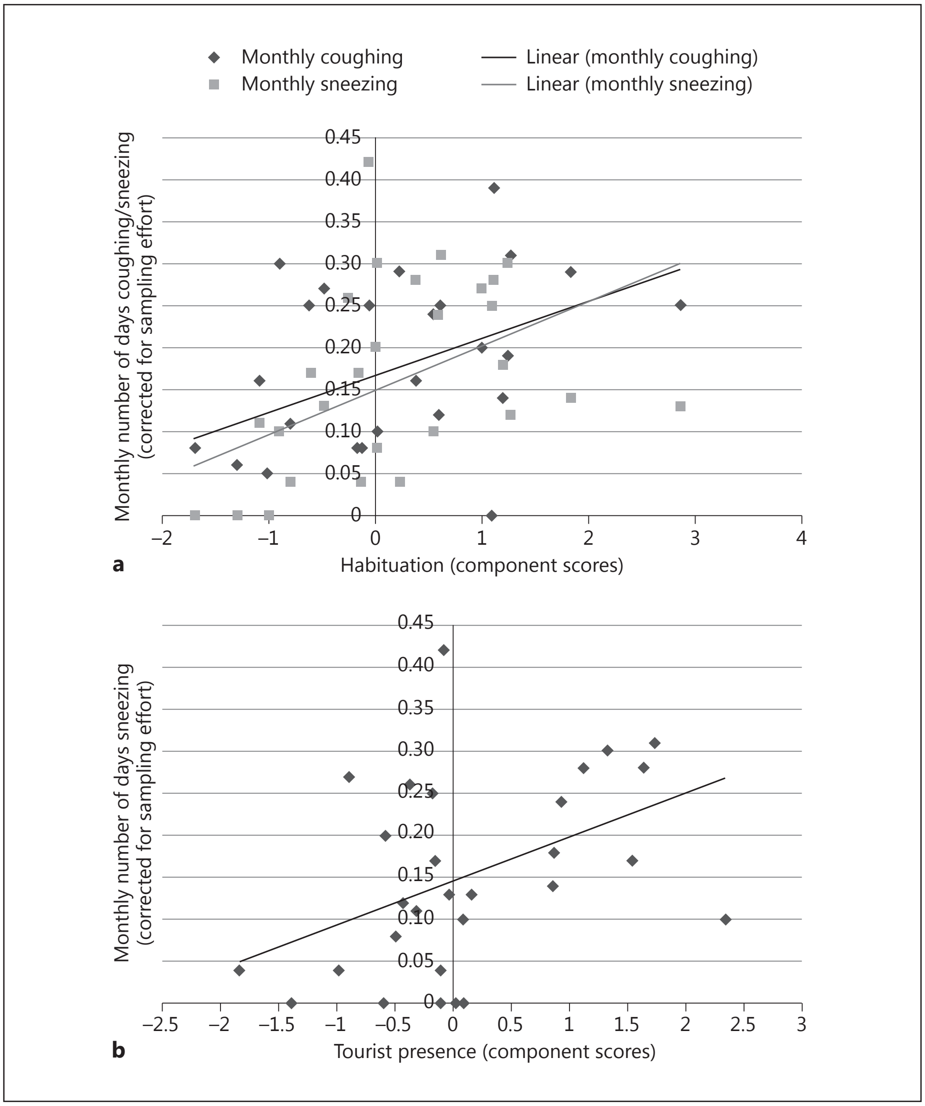

Fig. 3. Relationship between habituation component scores and the monthly number of days with gorilla coughing and sneezing (**a**), and tourist presence component scores and the monthly number of days with gorilla sneezing (**b**). Monthly sneezing and coughing are corrected for the number of days in which observations were recorded within the group.

be significantly more prevalent in the dry season (t = 3.36, p < 0.01, d.f. = 10). We observed ticks on the eyelids of every age-sex class except for the silverback, and in some extreme cases they covered the entire upper and lower eyelids of the gorillas. In another 5 cases of eye problems, no ticks were detected on the eyelids, but the timing of these events coincided with the peak dry season and these clinical signs were similar to tick-related cases (drainage, inflammation, crusty discharge). The remaining 7 eye cases were of unknown cause.

Diarrhoea (3.0% of health events) occurred rarely during the study period and 91.0% of these events were recorded within a day of an intergroup interaction with other gorillas. *Skin/hair conditions* (<1.0% of health events) were observed on 3 infants. Clinical signs associated with these conditions consisted of itchiness (persistent scratching) and temporary hair loss around a white patch of scaly skin. These cases were overlapping but spaced approximately 3 months apart (at first appearance), and persisted for about 6 months. The mildest case occurred in the oldest infant (3 years old) who had a single white scaly patch that was <2 cm in diameter, and the worst case occurred in the youngest infant (<1 year old) who had patches covering its entire body. Even though these skin conditions were overlapping, other individuals who were in frequent physical contact (e.g. the infants' mothers) did not show any of these clinical signs.

Our remaining observations (4.4%) were classified as *'other signs'*, including 2 incidents of lethargy (i.e. despondent, no appetite, frequent resting, and moving slowly) in 2 juveniles lasting around 4 days and occurring 2 weeks apart. We also recorded 2 occurrences of vomiting by 2 juveniles, both of which showed normal behaviour before and after the incident: (1) one juvenile descending from a tree where he had been rapidly feeding on *Dialium* sp. fruit, and (2) another juvenile vomiting (and afterwards, re-ingesting) a bright yellow liquid into his hand after drinking water from a stagnant pool. Records also included 3 cases of constipation (with signs lasting no more than a day) and 5 observations of individuals refraining from using a leg or arm for support (n = 3 lasting a few days, and n = 2 lasting 2 weeks). Finally, on 1 occasion we observed blood in urine along the group's trail in association with fresh faeces from an adult female or a subadult individual, probably due to normal female cycling [Mitchell et al., 1982].

Gorilla Demography

Between 2002 and 2004, the study group increased in size by 55.6% as a result of 4 births. Between 2004 and 2007, group size was maintained at 13 individuals as the result of 3 additional births, 2 natural emigrations (1 subadult and 1 adult female) and 1 accidental death of a 22-month-old infant who fell from a tree (the only known death recorded in the group during this period). Births were evenly distributed among 3 of the 4 adult females of the group, each having 2 birth events; the fourth female gave birth only once.

Discussion

Respiratory Events

We recorded coughs and sneezes on over half of the days we observed the gorillas. Most respiratory events were isolated cases that were not persistent over time (i.e. once/twice on any given day), and were seemingly independent of any symptomatic indication of a possible respiratory infection (in contrast to a 2012 outbreak in the same study group; Bai Hokou long-term data). However, the number of days in which coughs and sneezes were recorded significantly increased over the course of this study. The habituation PCA component (characterized by minimum distance to the gorillas and their visibility) was the single best predictor of monthly variation in both coughing and sneezing (table 3). Tourist presence (characterized by visibility and time spent with the gorillas) was also significantly related to sneezing.

Even though we attempted to control for choking (see Methods), our data likely include some baseline level of coughs and sneezes resulting from non-disease-related factors such as dust, allergens or choking. Moreover, in a recent paper, the study group was found to be affected by *Mammomonogamus* sp., a nematode lungworm that may also provoke coughing [Masi et al., 2012a]. However, since the gorillas approached observers more closely (and vice versa) as they became more habituated over time (from approx. 10 m in 2005 to approx. 7 m in 2007), the change in distance of only a few metres may also have impacted their health, resulting in an increase in clinical signs. Still, we cannot rule out the possibility that our ability to visually and audibly detect respiratory events also increased alongside the group's habituation. None of the possibilities discussed here are mutually exclusive, and indeed analyses of biological samples will provide the only definitive answers. Nevertheless, the aim of this study is not to define causality between human presence and respiratory observations, but merely to discuss how data on clinical signs can be useful to site managers for identifying situations where laboratory analyses are required. Additionally, even though recording coughs and sneezes among habituated primates cannot be used to identify respiratory infections, we reiterate that clinical signs may provide information to *supplement* one's diagnosis from biological samples. Indeed, unlike biological samples, which are collected less frequently and/or opportunistically (e.g. when an animal is ill), clinical signs can be collected daily, without cost, and on a more regular timescale.

Our results on respiratory clinical signs are strikingly different to what has been reported at other long-term ape habituation sites, which report dramatic outbreaks of visibly symptomatic respiratory infections resulting in mortality. Indeed, outbreaks of respiratory disease have been more frequently reported in habituated chimpanzees than in habituated gorillas [reviewed in Fujita, 2011]. This difference may be ascribed to such factors as the size of interacting cohorts (which promote disease transmission within groups [Kuehl et al., 2008]), the degree of sociality [Masi et al., 2012b], the longer time required to habituate a western gorilla group [Doran-Sheehy et al. 2007], species differences in how symptoms are expressed, and/or phylogenetic proximity to humans. Lastly, cross-site differences in staff and tourist visitations during the early stages of habituation, the relative isolation of the field site, and physical differences in undergrowth and forest cover [Chapman et al., 2005; Goldberg et al., 2008; Bonnell et al., 2010] may also have played a role.

Diarrhoea

Human diseases commonly spread by faecal-oral transmission (e.g. diarrhoea) have been documented at other great ape field sites [Nizeyi et al., 2001; Williams et al., 2008]. In our study, despite diarrhoea being a common complaint among the local staff at Bai Hokou (who as a result had no contact with the gorillas until treated), it occurred very rarely among the gorillas. Instead, the majority of diarrhoel events were recorded within at least 1 day of an interunit interaction with other gorillas, and it is under such stressful circumstances that gorillas are known to commonly exhibit diarrhoea [Schaller, 1963].

We also checked the gorillas' nests daily, which provided a more systematic method of monitoring emerging diarrhoea within the group. However, diarrhoea was never observed at nest sites, suggesting the absence of any *persisting* diarrhoea problem within the group during this study.

Other Clinical Signs

The other clinical signs observed among the gorillas occurred at surprisingly low frequencies, and did not significantly increase over time suggesting that western gorillas generally might have low rates of 'external signs' of illness despite having high faecal and urinary infections [Masi et al., 2012a]. Wounding was typically associated with falls from trees to gain access to food, inter- and intragroup aggression, and interspecies encounters (e.g. elephants). The gorillas also appeared to suffer from eye conditions caused by heavy infestation of ticks around the ophthalmic area, which in comparison has not been recorded in chimpanzees [Krief, pers. commun.; Krief et al., 2005], and may reflect the fact that western gorillas rarely engage in social grooming [Masi et al., 2009]. Tick presence around the gorillas' eyes occurred significantly more during the dry season, possibly as a consequence of higher tick presence on body height foliage during drier periods [pers. observation]. Lastly, regarding skin problems, we found no evidence for yaw lesions as previously described in a neighbouring western gorilla population in the Republic of Congo [Levréro et al., 2007]. We recorded 3 cases of white scaly patches occurring among infants (n = 3). Despite the close proximity of other group members (e.g. infants' mothers), the same clinical signs did not spread to other group members; this symptom may be similar to the dermatophytosis described for Mahale chimpanzees [Nishida et al., 2007].

Gorilla Demography

Stressed or unhealthy females are predicted to have reduced fertility and extended interbirth intervals [Dawson and Bartolotti, 2001; Dobson et al., 2003; Keele et al., 2009]. The study group grew in size from the start of their habituation (n = 9 in 2002) and remained stable at 13 individuals during the 3 years of this study. All adult females gave birth regularly, and the group's female interbirth intervals are the shortest that have been documented for this gorilla species [Robbins et al., 2004; Van der Weyde et al., in preparation]. However, the constant presence of humans near the study group may have discouraged immigration of new females, and thus may have slightly impacted the demography of the study group. Nevertheless, the near-continuous presence of humans for nearly a decade did not appear to negatively influence individual female reproductive rates.

Moreover, our results on the mortality rate are in contrast to the high rates of mortality reported from other ape habituation sites that were mainly caused by epidemics of infectious diseases, which seem to not have occurred thus far in our study group [Wallis and Lee, 1999; Mudakikwa et al., 2001; Leendertz et al., 2006a, b; Boesch, 2008; Kaur et al., 2008; Köndgen et al., 2008; Williams et al., 2008; Palacios et al., 2011]. The difference may be due to environmental constraints (e.g. seasonal availability of food, and/or density and availability of infectious vectors or parasites [Gogarten et al., 2012]) or for anthropogenic reasons (e.g. human contact from local villagers, researchers, and/or tourists).

Conclusion

As our data are only representative of a single gorilla group from one field location, future studies must strive to determine how clinical signs vary between social groups and sites. Unlike other great ape species, which have more flexible grouping patterns, all members of a western gorilla group experience a near-continuous human presence when habituated. It is therefore surprising that despite the habituation of the study group, group-wide 'outbreaks' of symptomatic illness were not detected as in observational studies of chimpanzees, and reproductive success was high while mortality was low. The rigid application at Bai Hokou of basic protocols to avoid anthropogenic disease transmission to the study group (table 1) may have contributed to our findings.

Funding and infrastructure are often limited during the early stages of great ape habituation, and it is therefore often impractical to frequently collect and screen urine/faeces for pathogens from known individuals. As such, long-term baseline records of clinical signs may help identify times when biological sampling or a clinical intervention is necessary (but for symptomatic infections only). With this study, we would like to encourage field workers to record long-term baseline data on clinical signs within their study groups because they are inexpensive and easy to collect, and may provide useful information on general health patterns. However, clinical signs must be used to supplement information obtained from biological sampling because certain illnesses may not always show easily detectable clinical signs. The recent development of more sophisticated non-invasive sampling methods [Köndgen et al., 2010] will provide data that complement studies like the one we present here, and enable us to further explore the nature of clinical signs and ill health in habituated great apes, particularly western gorillas.

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