

Effects of logging on gastrointestinal parasite infections and infection risk in African primates

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Summary

1. The impact of habitat disturbance on biodiversity conservation and animal health is poorly understood. Selective logging results in a suite of alterations that may increase infection risk and susceptibility to infection in resident populations.
2. The aim of this study was to improve our understanding of this interplay by examining the effects of logging on infection risk and gastrointestinal parasite infections in three primate species whose populations have responded differently to selective logging in Kibale National Park, Uganda. Populations of redbelt guenons *Cercopithecus ascanius* are declining in logged forest; red colobus *Piliocolobus tephrosceles* populations are in a state of slow recovery; and black-and-white colobus *Colobus guereza* populations are increasing in logged forest.
3. We collected faecal samples from these three primate species over a period of 5 years in logged and undisturbed forest, to compare parasite infection prevalence and the magnitude of multiple infections. We also analysed canopy and ground vegetation plots to compare environmental contamination with primate parasites in logged and undisturbed forest.
4. The prevalence and richness of gastrointestinal helminth and protozoan parasite infections, and the magnitude of multiple infections were greater for redbelt guenons in logged than undisturbed forest, but these parameters did not differ between forest types for either colobine. Data from the canopy and ground vegetation plots revealed that infective stages of two representative generalist primate parasites occurred at higher densities in logged compared with undisturbed forest, signifying a greater infection risk for all primate species in logged forest.
5. *Synthesis and applications.* This study demonstrates that selective logging can be associated with changes in an important ecological association between hosts and parasites. Our results indicate that anthropogenic habitat change could influence patterns of parasite infection in primates with associated effects on population performance.

Key-words: *Cercopithecus*, colobus, disturbance ecology, selective logging, tropical forest

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Introduction

Knowledge of how particular species are affected by specific forms of anthropogenic environmental change is essential for developing sound conservation and management plans, as well as assessing the relative conservation value of various disturbed habitats. Selective logging is a dominant habitat disturbance pattern with

strong conservation potential (Frumhoff 1995; Struhsaker 1997; FAO 1999; Chapman & Peres 2001). A multitude of studies have examined the effects of selective logging on the abundance and diversity of invertebrate (Hill 1999; Basset *et al.* 2001; Davis *et al.* 2001; Hamer *et al.* 2003) and vertebrate taxa (Johns & Skorupa 1987; Johns 1992; Heydon & Bulloh 1997; Marsden 1998; Robinson & Robinson 1999). Although logging often results in a reduction in overall diversity, effects on individual species are difficult to predict.

Primates have been the focus of much research concerning the impact of logging (Johns & Skorupa 1987; Plumptre & Reynolds 1994; Johns 1997; Struhsaker 1997; Chapman *et al.* 2000). Although logging is known to reduce the abundance of some primate species, the proximate mechanism for these declines remains unknown. The potential role of parasite infections in such primate population declines remains largely unexplored.

Selective logging results in a suite of alterations in host ecology and forest structure that may alter infection prevalence and infection risk in resident populations. Patterns of parasitism in wildlife populations are influenced by host ranging patterns, density, intra-specific and interspecific contact rates and diet (Hudson *et al.* 2002; Nunn *et al.* 2003). Studies on a variety of species have demonstrated that these characteristics can be affected by changes in forest structure (Olupot *et al.* 1994; Heydon & Bulloh 1997; Patriquin & Barclay 2003).

Our study aimed to improve understanding of this interplay between forest structure and host behaviour by examining the effects of selective logging on patterns of parasitism in three primate species whose populations have responded differently to selective logging in Kibale National Park, Uganda (Chapman *et al.* 2000): redtail guenon *Cercopithecus ascanius* populations are declining in logged forest; red colobus *Piliocolobus tephrosceles* populations are in a state of recovery in logged forest; and black-and-white colobus *Colobus guereza* populations are increasing in logged forest (Chapman *et al.* 2000). We hypothesized that interspecific differences in performance in selectively logged forest will be related to differences in gastrointestinal parasite infections. We compared the prevalence, richness and number of gastrointestinal parasite species infecting individuals, and the relative infection risk between primates from logged and undisturbed forests. We proposed explanations for the similarities and differences in the patterns of parasitism between these forests and addressed the implications of these findings for conservation and management.

Methods

STUDY SITE

Kibale National Park (795 km²) is located in western Uganda (latitude 0°13'–0°41'N, longitude 30°19'–30°32'E) near the base of the Rwenzori Mountains (Chapman & Lambert 2000). Tall, closed-canopy forest

accounts for approximately 57% of the park. The remainder of the park comprises a mosaic of swamp (4%), grasslands (15%), pine plantations (1%) and colonizing forest (19%) (Chapman & Lambert 2000). The study site, Kanyawara, is located at the northern end of the park at an altitude of 1500 m a.s.l. (Gillespie & Chapman 2001). Kanyawara experiences a bimodal pattern of seasonal rainfall, with peaks occurring in March–May and August–November. Mean annual rainfall (1990–2001) is 1749 mm (Chapman, Chapman & Gillespie 2002). Daily temperature minima and maxima averaged 14.9 °C and 20.2 °C, respectively, from 1990 to 2001.

Prior to becoming a national park in 1993, Kibale was a Forest Reserve, gazetted in 1932 to provide sustained production of hardwood timber (Osmaston 1959). A polycyclic felling cycle of 70 years was initiated (Kingston 1967). This history of logging has led to varying degrees of disturbance among sites. We conducted our study in two forestry compartments, one logged at high intensity in the late 1960s (K-15) and one undisturbed (K-30). The K-15 forestry compartment is a 347-ha section of forest that experienced high-intensity, selective felling from September 1968 to April 1969. Total harvest averaged 21 m³ ha⁻¹, or approximately 7.4 stems ha⁻¹ (Struhsaker 1997), but incidental damage was much higher. It is estimated that approximately 50% of all trees in this compartment were destroyed by logging and incidental damage (Johns & Skorupa 1987; Skorupa 1987). Many of the harvested tree species are primate food trees (Struhsaker 1997; Chapman *et al.* 2000). K-15 will be referred to henceforth as logged forest. The K-30 forestry compartment is a 282-ha area that has not been commercially harvested. Prior to 1970, however, a few large stems (0.03–0.04 trees ha⁻¹) were removed. This extremely low level of extraction seems to have had little effect on the structure and composition of the forest (Skorupa & Kasenene 1984; Struhsaker 1997). Hence, compartment K-30 served as a control plot for our comparisons. As a control, we assumed that differences between the undisturbed compartment and the logged compartment were the result of the effects of logging. This was not ideal, as some differences could be the result of naturally occurring variation in forest structure. However, these compartments were in close proximity (< 2 km apart) and there were few marked differences between them in terms of physical characters that influence forest structure. K-30 will henceforth be referred to as undisturbed forest.

The logged and undisturbed forests lie within a much larger continuous forest block and are separated by forest that experienced low-intensity logging in the late 1960s. This continuous forest block has been protected from human exploitation since the 1970s, and the hunting of primates ceased in the region in the early 1960s (Struhsaker 1997). Consequently, we assumed that the risk of anthrozoönotic infection had not differed between the two areas for three decades.

Table 1. Number of faecal samples collected, size of population sampled and density of redbtail guenon *Cercopithecus ascanius*, red colobus *Piliocolobus tephrosceles* and black-and-white colobus *Colobus guereza* in logged and undisturbed forest at Kibale National Park, Uganda

Primate species	Samples analysed		Population size		Population density (animals ha ⁻¹)	
	Logged	Undisturbed	Logged	Undisturbed	Logged	Undisturbed
Redtail guenon	38	119	54	381	0.16	1.35
Red colobus	127	561	462	620	1.33	2.20
Black-and-white colobus	125	106	288	51	0.83	0.18

FAECAL SAMPLING AND ANALYSIS

Of the eight diurnal primate species that inhabit Kibale National Park, we restricted our comparison to redbtail guenon, red colobus and black-and-white colobus, the three species providing multiple habituated groups known to range exclusively in either logged or undisturbed forest. Redtail guenons are frugivorous primates that display a one male–multifemale social structure and live in groups of seven to 35 individuals (Cords 1987). Red colobus are folivorous primates that display a multimale–multifemale social structure and live in groups of 20 to more than 100 (Struhsaker 1975; Gillespie & Chapman 2001). Black-and-white colobus are folivorous primates that display a variable social structure (one male–multifemale and multimale–multifemale) and live in groups of seven to 11 (Oates 1974; Onderdonk & Chapman 2000).

From August 1997 to August 2002, we collected 1076 faecal samples from these three primate species in logged and undisturbed forest. Every attempt was made to sample as widely as possible within each primate population; however, as individual recognition was not possible, it is likely that some individuals were sampled more than once. Number of samples collected, estimated population size and estimated population density for each of the three primate species in logged and undisturbed forest can be found in Table 1. Populations sampled were homogeneous with regard to sex ratio, age structure and social structure, and daily and seasonal sampling were equivalent between areas. All samples were collected immediately after defecation to avoid contamination, and they were examined macroscopically for adult nematodes and tapeworm proglottids. Samples were stored individually in 5.0-mL vials in a 10% formalin solution. Preserved samples were transported to the University of Florida (Florida, USA), where they were examined for helminth eggs and larvae and protozoan cysts using concentration by sodium nitrate flotation and faecal sedimentation (Sloss, Kemp & Zajac 1994). Parasites were counted and identified on the basis of egg or cyst colour, shape, contents and size. Iodine was used to facilitate protozoan identification. Measurements were made to the nearest 0.1 micron \pm SD using an ocular micrometer fitted to a compound microscope. Unknown parasites were photographed for later identification. Coprocultures ($n = 10$ per pri-

mate species) and opportunistic necropsies of animals found dead in the forest ($n = 4$ colobines) (Ministry of Agriculture, Fisheries and Food 1979) were used to match parasite eggs to larvae and adult worms for positive identification (Gillespie 2004). As taxonomic accounts of the gastrointestinal parasites of most wild primates are unavailable, we often identified parasites to the genus or family level. Descriptions of taxa, mode of infection and associated pathology for each parasite species recovered are given in Table 2.

INFECTION RISK ASSESSMENT

As an index of infection risk, infective-stage parasite densities were determined for canopy vegetation, ground vegetation and soil plots from logged and undisturbed forest. From January to August 2002, we collected 28 1-m³ vegetation plots at a height of 12 m from canopy trees used within the previous 2 h by red colobus, 14 from logged forest and 14 from undisturbed forest. As there is high overlap in food trees among redbtail guenons, red colobus and black-and-white colobus, the plots sampled represented viable guenon and colobus habitat. Canopy access for plot collection was facilitated by the single rope climbing technique (Mitchell 1982; Laman 1995; Houle, Chapman & Vickery 2004). Twenty-eight 1-m³ ground vegetation plots were collected below trees sampled for canopy plots. Soil plots (0.05 m² surface scratches) were collected within selected ground vegetation plots, 10 from logged forest and 10 from undisturbed forest. We used a modified sedimentation technique to recover infective-stage parasites from vegetative plots (Sloss, Kemp & Zajac 1994). Soil plots were examined using a modified Baermann method (Sloss, Kemp & Zajac 1994). Samples from all plots were examined by dissecting and compound microscope, and infective-stage individuals of the two most prevalent parasite species shared by all three primate species, *Trichuris* sp. (eggs) and *Oesophagostomum* sp. (L3 larvae), were counted.

STATISTICAL ANALYSES

We employed chi-squared tests of independence to compare the prevalence of infection between logged and undisturbed forests for overall and specific infections for each of the three primate species. As the datasets for

Table 2. Mode of infection, morbidity and mortality associated with gastrointestinal parasites infecting redtail guenon *Cercopithecus ascanius*, red colobus *Piliocolobus tephrosceles* and black-and-white colobus *Colobus guereza* in logged and undisturbed forests at Kibale National Park, Uganda

Parasite species	Mode of infection	Morbidity/mortality	Sources
<i>Oesophagostomum</i> sp.	Larvae ingested	Severe diarrhoea, weight loss, death	Crestian & Crespeau (1975), Roperto <i>et al.</i> (1985)
<i>Entamoeba histolytica</i>	Cyst or trophozoite ingested	Hepatic and gastric amoebiasis, death	Loomis (1983)
<i>Strongyloides fulleborni</i>	Larvae ingested, skin penetration	Mucosal inflammation, ulceration, death	McClure & Guilloud (1971), Pampiglione & Ricciardi (1972)
<i>Trichuris</i> sp.	Larvated egg ingested	Typically asymptomatic	Beaver, Jung & Cupp (1984), Baskin (1993)
Dicrocoeliid liver fluke	Metacercaria ingested in ant	Typically asymptomatic	Beaver, Jung & Cupp (1984), Coombs & Crompton (1991)
<i>Giardia lamblia</i>	Cyst ingested	Typically asymptomatic, possibly epizoonotic	Fiennes (1967), Baskin (1993)
<i>Entamoeba coli</i>	Cyst or trophozoite ingested	Typically asymptomatic	Beaver, Jung & Cupp (1984)
<i>Streptopharagus</i> sp.	Intermediate host ingested (cockroach, beetle)	Typically asymptomatic	Beaver, Jung & Cupp (1984), Coombs & Crompton (1991)
<i>Chilomastix mesnili</i>	Cyst or trophozoite ingested	Typically asymptomatic	Beaver, Jung & Cupp (1984)
<i>Iodameoba buetschlii</i>	Cyst or trophozoite ingested	Typically asymptomatic	Beaver, Jung & Cupp (1984)

the comparison of magnitude of multiple infections and the dataset for the infection risk assessment both followed a normal distribution and met the assumption of equality of variance, independent sample *t*-tests were performed. This allowed us to compare the number of parasite species infecting individual primates and the density of infective-form parasites in vegetative plots between logged and undisturbed forest.

Results

The prevalence of infection with *Trichuris* sp., *Oesophagostomum* sp., *Entamoeba coli*, *Entamoeba histolytica*, *Iodameoba buetschlii*, *Strongyloides fulleborni* and *Streptopharagus* sp. was higher for redtail guenons from logged forest compared with guenons from undisturbed forest (Table 3). Only redtail guenons from logged forest

were infected with a dicrocoeliid liver fluke, *Chilomastix mesnili* and *Giardia lamblia* (Table 3). There were no species of parasite found only in undisturbed forest. The number of parasite species infecting individual redtail guenons was greater in logged compared with undisturbed forest ($t = 5.74$, $P < 0.001$; Fig. 1).

Prevalence of infection did not differ between red colobus from logged ($n = 127$) and undisturbed ($n = 561$) forest for any of the five parasites documented (*Trichuris* sp., *Oesophagostomum* sp., *Strongyloides fulleborni*, *Entamoeba coli* and *Entamoeba histolytica*; Table 4). The mean number of parasite species infecting individual red colobus did not differ between logged and undisturbed forest ($t = 1.32$, $P = 0.186$; Fig. 1).

Prevalence of infection did not differ between black-and-white colobus from logged ($n = 125$) and undisturbed ($n = 106$) forest for any of the six parasites documented (*Trichuris* sp., *Oesophagostomum* sp.,

Table 3. Prevalence (%) of gastrointestinal parasite infections in redtail guenon *Cercopithecus ascanius* from logged and undisturbed forests in Kibale National Park, Uganda ($n =$ samples analysed)

Parasite species	Logged ($n = 38$)	Undisturbed ($n = 119$)	Significance
<i>Trichuris</i> sp.	63	21	***
<i>Oesophagostomum</i> sp.	21	3	***
<i>Entamoeba coli</i>	26	5	***
<i>Entamoeba histolytica</i>	26	5	***
<i>Iodameoba buetschlii</i>	26	5	***
<i>Strongyloides fulleborni</i>	16	4	**
<i>Streptopharagus</i> sp.	32	13	*
Dicrocoeliid liver fluke	11	0	–
<i>Chilomastix mesnili</i>	8	0	–
<i>Giardia lamblia</i>	26	0	–
Overall	92	29	***

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$; – no chi-square test performed as one forest type had 0 prevalence.

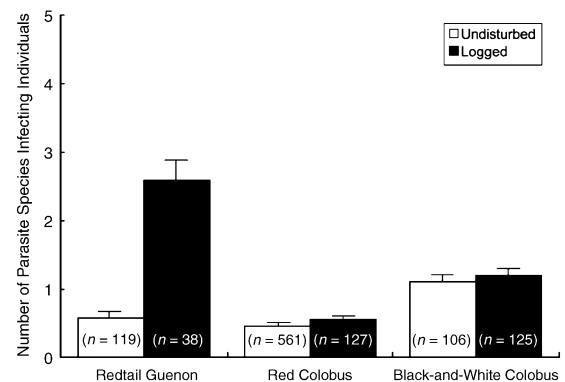
**Fig. 1.** Number of parasite species infecting individual redtail guenon *Cercopithecus ascanius*, red colobus *Piliocolobus tephrosceles* and black-and-white colobus *Colobus guereza* in undisturbed and logged forest at Kibale National Park, Uganda. n , numbers of faecal samples evaluated; bars represent standard error.

Table 4. Prevalence (%) of gastrointestinal parasite infections in red colobus *Ptilocolobus tephrosceles* from logged and undisturbed forests in Kibale National Park, Uganda (n = samples analysed)

Parasite species	Logged ($n = 127$)	Undisturbed ($n = 561$)	Significance
<i>Trichuris</i> sp.	40	36	NS
<i>Oesophagostomum</i> sp.	5	2	NS
<i>Strongyloides fulleborni</i>	1	4	NS
<i>Entamoeba coli</i>	6	3	NS
<i>Entamoeba histolytica</i>	6	3	NS
Overall	45	37	NS

NS, $P > 0.05$.

Strongyloides fulleborni, the dicrocoeliid liver fluke, *Entamoeba coli* and *Entamoeba histolytica*; Table 5). The mean number of parasite species infecting individual black-and-white colobus did not differ between logged and undisturbed forest ($t = 0.64$, $P = 0.524$; Fig. 1).

Trichuris sp. eggs were more abundant in canopy plots and ground vegetation plots from logged compared with undisturbed forest (Table 6). *Oesophagostomum* sp. L3 larvae were more abundant in ground vegetation plots from logged compared with undisturbed forest, but were not found in canopy plots (Table 6). No infective-stage primate parasites were identified from the soil plots.

Discussion

The results of our study demonstrate that redbtail guenons in logged forest at Kibale National Park have a higher prevalence of all seven gastrointestinal parasite species recorded for guenons in both logged and undisturbed forest, and three additional parasite species that only occur in guenons in logged forest. Additionally, we found that redbtail guenons in logged forest have more parasite species concurrently infecting individuals than guenons in undisturbed forest. In contrast, we found that none of these parameters differed between logged and undisturbed forest for red colobus and black-and-white colobus, despite the risk of infection by two generalist parasites being higher for all three primate species in logged forest. These results support our hypothesis that interspecific differences in performance in selectively logged forest correlate with differences in gastrointestinal

Table 5. Prevalence (%) of gastrointestinal parasite infections in black-and-white colobus *Colobus guereza* from logged and undisturbed forests in Kibale National Park, Uganda (n = number of samples analysed)

Parasite species	Logged ($n = 125$)	Undisturbed ($n = 106$)	Significance
<i>Trichuris</i> sp.	79	84	NS
<i>Oesophagostomum</i> sp.	9	9	NS
<i>Strongyloides fulleborni</i>	4	3	NS
<i>Dicrocoeliid liver fluke</i>	1	1	NS
<i>Entamoeba coli</i>	16	9	NS
<i>Entamoeba histolytica</i>	16	9	NS
Overall	79	84	NS

NS, $P > 0.05$.

parasite infections. This establishes that selective logging can be associated with changes in host-parasite systems.

The patterns of parasitism in wildlife populations are influenced by characteristics of the host, such as ranging patterns, density, intraspecific and interspecific contacts and diet (Hudson *et al.* 2002; Nunn *et al.* 2003). Behavioural studies of redbtail guenons (Stickler 2003; K. Rode, unpublished data), red colobus (Chapman, Wasserman & Gillespie 2005) and black-and-white colobus (Chapman, Wasserman & Gillespie 2005) in logged and undisturbed forest at Kibale National Park quantify how these characteristics are affected by logging. Animals with larger home ranges and longer day ranges are expected to encounter more parasites, resulting in higher infection prevalence and higher parasite richness (Poulin 1998; Nunn *et al.* 2003). Redtail guenons in logged forest at Kibale have larger home ranges and longer day ranges compared with guenons in undisturbed forest (Stickler 2003). In contrast, these ranging patterns do not differ between logged and undisturbed forest for either of the colobines (Chapman, Wasserman & Gillespie 2005). Hence, altered guenon ranging patterns in logged forest may contribute to the altered pattern of parasitism observed.

Host density is considered to be of central importance to infection rates in directly transmitted parasites (Poulin 1998), and within-species studies have demonstrated that host density correlates positively with parasite prevalence and diversity (Morand & Poulin 1998;

Table 6. Mean density of infective forms (infective forms m^{-3}) of *Trichuris* sp. (eggs) and *Oesophagostomum* sp. (L3 larvae) in canopy and ground vegetation plots from logged and undisturbed forest in Kibale National Park, Uganda ($n = 14$ plots for each treatment)

Parasite species	Logged (infective forms m^{-3})		Undisturbed (infective forms m^{-3})		t	P
	Canopy	Ground	Canopy	Ground		
<i>Trichuris</i> sp.	1.43 \pm 0.20	4.21 \pm 0.13	0.47 \pm 0.25	0.43 \pm 0.96	-2.66	0.013
<i>Oesophagostomum</i> sp.	0	3.93 \pm 1.23	0	0.14 \pm 0.11	-3.14	0.008

Packer *et al.* 1999). Logging at Kibale has resulted in considerable differences in density between logged and undisturbed areas for redbtail guenons, red colobus and black-and-white colobus (Chapman *et al.* 2000). However, patterns of host density do not correlate with infection prevalence or richness. Consequently, the patterns of parasitism observed in redbtail guenons in logged forest at Kibale do not appear to be linked to density-dependent factors.

Intraspecific contact rates are predicted to correlate with parasite prevalence and diversity, as the frequency of contact between infected and uninfected individuals increases as group size increases. This prediction is confirmed by empirical studies of group-living animals (Freeland 1979; Davies *et al.* 1991; Phillippi & Clarke 1992; Côté & Poulin 1995). Group sizes of both redbtail guenons and red colobus are smaller in logged compared with undisturbed forest, whereas black-and-white colobus groups are of equivalent size in logged and undisturbed forest at Kibale (Chapman *et al.* 2000; Stickler 2003; Chapman, Wasserman & Gillespie 2005). In addition, polyspecific associations among these primate species, which increase contact rates and effectively increase group size, are twice as common in undisturbed compared with logged forest at Kibale (Struhsaker 1997; Stickler 2003). Consequently, the patterns of parasitism observed in redbtail guenons in logged forest at Kibale do not appear to be the result of changes in intraspecific or interspecific contact rates.

Diet may influence host exposure to parasites as well as susceptibility to infection. Encounter probabilities for some of the parasites documented in our study are expected to differ between guenons and colobines. *Dicrocoeliidae* sp. and *Streptopharagus* sp. have intermediate hosts. Guenons feed on many of these intermediate hosts, while colobines do not intentionally feed on insects and other invertebrates. Consequently, if intermediate hosts are more common in logged forests or if more intermediate hosts are infected in logged forests, guenons may have a higher encounter probability for parasites with indirect life cycles. Logging at Kibale resulted in the removal or destruction of approximately 50% of trees, many of which were primate food trees (Struhsaker 1997; Chapman *et al.* 2000). Multiple indices of fruit production demonstrate lower fruit availability in the logged compared with undisturbed forests even 25 years after logging at Kibale (Chapman & Chapman 1997), and colonization in logged forest at Kibale has been dominated by two preferred colobine food species (*Celtis durandii* and *Funtumia latifolia*; Chapman & Chapman 2004). Thus, patterns of regeneration in logged forest at Kibale may be more favourable for colobus monkeys than for the guenons.

Recent evidence from Kibale indicates that reduced food availability has resulted in dietary stress in redbtail guenons in logged forests (Chapman, Wasserman & Gillespie 2005; K. Rode, unpublished data). These guenons have a lower intake of crude protein and key minerals compared with guenons in undisturbed forests

(K. Rode, unpublished data). Such protein and mineral deficiencies have been linked to depressed immune function (Chandra 1983; Bundy & Golden 1987; Koski & Scott 2001). In addition, nutrient content varies more among food items for guenons compared with colobines at Kibale (Chapman, Wasserman & Gillespie 2005; K. Rode, unpublished data). Thus, variation in nutritional condition is likely to be more sensitive to changes in habitat for guenons than for colobines. Hence, dietary stress may increase susceptibility of redbtail guenons in logged forest to infection, contributing to the altered pattern of parasitism observed.

Several factors may explain the higher density of infective forms of *Trichuris* sp. and *Oesophagostomum* sp. in vegetation plots in primate habitat in logged compared with undisturbed forest. Logging may result in increased overlap among conspecifics because of reduced pathways for travel and reduced feeding tree densities (Freeland 1980; Hausfater & Meade 1982; Gilbert 1997). In addition, logging may result in higher foliage density (Ganzhorn 1995). This may result in a greater surface area exposed to falling faeces. Lastly, assuming that the intensity of parasite infections is higher, primates in the logged forest may be shedding greater numbers of parasite eggs into the environment. Any of these three scenarios could result in an increased probability of contact with infected faecal material.

SYNTHESIS AND APPLICATIONS

This study demonstrates that patterns of parasitism differ between logged and undisturbed forest for redbtail guenons at Kibale National Park in Uganda. Logging in Kibale is known to impact these frugivorous guenon populations more than the folivorous colobine populations, and increased parasite infections in redbtail guenons may contribute to these patterns. In addition, evidence suggests that generalist parasites predominate among Kibale's primates (Gillespie, Greiner & Chapman 2004; Gillespie, Greiner & Chapman 2005), thus cross-species interaction may be an important source of infection risk (Ezenwa 2003). As with other related sympatric species, Kibale's primates may act as reservoirs, maintaining a high infection risk by parasites that may be detrimental to redbtail guenons, even as redbtail guenon densities decline (McCallum & Dobson 2002; Lafferty & Holt 2003). Considering the central role that parasites play in their hosts' dynamics (Hudson, Dobson & Newborn 1998; Hochachka & Dhondt 2000) and on community biodiversity (Hudson *et al.* 2002), future research is needed to test the generality of our findings and to investigate linkages between such changes and the performance of host populations in logged forest.

Although many recent studies and reviews have focused on the conservation implications of anthropozoonotic parasite transmission to wildlife (Stuart & Strier 1995; Wallis & Lee 1999; Nizeyi *et al.* 2001; Graczyk *et al.* 2002; Woodford, Butynski & Karesh 2002), the potential impact of anthropogenic habitat disturbance

on parasite infections in wild populations has received far less attention. This study demonstrates that one such disturbance, selective logging, is associated with altered patterns of parasitism for some species. Knowledge of how particular species are affected by various forms of ecological change is essential to promote land-use policy that is compatible with animal and human health and biodiversity conservation.

Our understanding of how anthropogenic habitat change alters wildlife disease dynamics is in its infancy. Our comprehension of this interplay will be greatly improved by future research that investigates how anthropogenic habitat disturbance affects the rates and patterns of parasite transmission within and between species, and how such changes affect the performance of host populations. Identifying risk factors for disease transmission will improve the ability of conservationists to make rational decisions about the risks and benefits of timber extraction and management activities.

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