

Habituating the great apes: the disease risks

Michael H. Woodford, Thomas M. Butynski and William B. Karesh

Abstract All six great apes, gorillas *Gorilla gorilla* and *G. beringei*, chimpanzees *Pan troglodytes* and *P. paniscus*, and orang-utans *Pongo pygmaeus* and *P. abelii*, are categorized as Endangered on the 2000 IUCN Red List and face many threats to their continued existence in the wild. These threats include loss of habitat to settlement, logging and agriculture, illegal hunting for bushmeat and traditional medicine, the live ape trade, civil unrest and infectious diseases. The great apes are highly susceptible to many human diseases, some of which can be fatal while others can cause marked morbidity. There is increasing evidence that diseases can be transmitted from humans to free-living habituated apes, sometimes with serious consequences. If protective measures are not improved, ape populations that are frequently in close contact with people will eventually be affected by

the inadvertent transmission of human diseases. This paper describes the risks, sources and circumstances of infectious disease transmission from humans to great apes during and consequent upon habituation for tourism and research. A major problem is that the regulations that protect habituated apes from the transmission of disease from people are often poorly enforced. Suggestions are made for improving the enforcement of existing regulations governing ape-based tourism, and for minimizing the risk of disease transmission between humans, both local people and international visitors, and the great apes.

Keywords Chimpanzees, disease, gorillas, great apes, habituation, orang-utans, tourism.

Introduction

The great apes, gorillas *Gorilla gorilla* and *Gorilla beringei*, chimpanzees *Pan troglodytes* and *Pan paniscus*, and orang-utans *Pongo pygmaeus* and *Pongo abelii*, face many threats to their continued existence in the wild (Hilton-Taylor, 2000; Groves, 2001). These threats include loss of habitat to settlement, logging and agriculture, illegal hunting for bushmeat and traditional medicine, the live ape trade, civil unrest and infectious diseases (Amman, 2001; Butynski, 2001; Rijksen, 2001; Wilkie, 2001). All six species of great ape are categorized as Endangered on the 2000 IUCN Red List (Hilton-Taylor, 2000; Butynski, 2001).

'Close-contact' tourism is often proposed as the best way to guarantee the continued existence of the great apes and their habitats in Africa and South-east Asia (but see Butynski & Kalina, 1998). To render the shy forest dwelling apes more accessible to researchers and tourists, selected groups of apes are subjected to a

taming process known as habituation. This entails the gradual familiarization of the apes to the close presence of humans. In the case of gorillas, this process requires almost daily contact for 3–24 months (Butynski & Kalina, 1998). In the 1990s more than six new ape-habituation projects were initiated for research or tourism purposes in Central Africa alone (Butynski & Kalina, 1998). Habituation of orang-utans for tourism and research has taken place in Borneo and Sumatra (Karesh, 1995; Rijksen, 2001).

However, close contact carries with it considerable risks of disease transmission (Wolfe *et al.*, 1998; Homsy, 1999; Adams *et al.*, 1999, 2001; Wallis & Lee, 1999; Butynski, 2001), and increasing levels of research, tourism and protected area management have resulted in an increase in the frequency of close contact between humans and apes. The purpose of this paper is to draw attention to the risks of disease transmission from humans to free-ranging great apes that are subjected to habituation for tourism or research purposes in Africa and South-east Asia, and to suggest measures for reduction of this threat.

The risks

There is little published work on the diseases of free-living great apes (but see Cousins, 1972; Kalter, 1980; Ashford *et al.*, 1990, 1996; Wolfe *et al.*, 2001). Gorillas, chimpanzees and orang-utans are phylogenetically close to humans and are thus susceptible to many of the

Michael H. Woodford Quinta Margarida, Apartado 215, 8101 Loulé, Algarve, Portugal. E-mail: dinton@aol.com

Thomas M. Butynski Zoo Atlanta's Africa Biodiversity Conservation Program, National Museums of Kenya, P.O. Box 24434, Nairobi, Kenya. E-mail: tbutynski@aol.com

William B. Karesh (Corresponding author) Wildlife Conservation Society, 185 & Southern Blvd, Bronx, N.W. 10460, USA. E-mail: wkaresh@wcs.org

Received 3 August 2000. Revision requested 6 November 2000.

Accepted 21 November 2001.

infectious diseases of humans. Some of these diseases can be fatal, and others can cause marked morbidity with severe consequences for normal behaviour and reproduction (Kalter, 1980; Butynski, 2001). The main routes of transmission of human diseases to apes are respiratory (aerosol) and faecal-oral (Hudson, 1992; Kalema & Cooper, 1996; Butynski & Kalina, 1998; Homsy, 1999; Wallis & Lee, 1999). Contact with objects contaminated by disease, such as boots, clothes, used toilet paper and tissue handkerchiefs, and biting insects may also play an important role in the transmission of infectious diseases.

The great apes and humans share a considerable array of communicable diseases, including the common cold, pneumonia, influenza, hepatitis, smallpox, chicken pox, bacterial meningitis, tuberculosis, measles, rubella, mumps, yellow fever, paralytic poliomyelitis, encephalomyocarditis, and Ebola fever. Parasitic diseases are also shared, including malaria, schistosomiasis, giardiasis, filariasis, and infection with *Strongyloides* spp., *Entamoeba* spp., *Oesophagostomum* spp., *Acanthocephala* spp., *Cyclospora* sp., *Giardia* sp., and *Sarcoptes* sp. (Benirschke & Adams, 1980; Kalter, 1980, 1986; Toft, 1986; Ashford *et al.*, 1990, 1996; Meder, 1994; Smith *et al.*, 1996; Wolfe *et al.*, 1998; Homsy, 1999; Sleeman *et al.*, 2000; Wolfe *et al.*, 2001).

The introduction of human-borne infections into populations of wild great apes, especially when the population is small, could be catastrophic (May, 1988; McGrew *et al.*, 1989; Woodford, 1989; Kalina & Butynski, 1995; McCallum & Dobson, 1995; Butynski & Kalina, 1998; Homsy, 1999), and there is increasing evidence that diseases are transmitted from humans to free-living habituated apes (Goodall, 1971; Hastings *et al.*, 1991; Kortlandt, 1996). If protective measures are not improved, it is probable that ape populations that are subjected to frequent close contact with researchers, tourists, tourist guides or military escorts will be affected by the inadvertent transmission of a human disease (McGrew *et al.*, 1989; Sholley, 1989; Sholley & Hastings, 1989; Woodford, 1989; Murray, 1990; Hudson, 1992; Macfie, 1996; Butynski & Kalina, 1998; Butynski, 2001). Large numbers of humans in close contact with small populations of apes may result in a disaster similar to that seen with canine distemper virus in African wild dogs *Lycaon pictus* and lions *Panthera leo* in contact with domestic dogs in the Serengeti ecosystem of Tanzania (Alexander & Appel, 1994; Roelke-Parker *et al.*, 1996).

Several factors can influence the likelihood of disease transmission to habituated great apes. The most important of these include the health status and epidemiological backgrounds of those humans entering the habitats of the great apes (Adams *et al.*, 1999, 2001). Some diseases carried by humans and their domestic animals can cross the species barrier and may cause rapid mortality in the

new hosts (Rossiter, 1990; Holmes, 1996; Butynski, 2001). Small populations living in fragmented, unstable ecosystems may be at particular risk (May, 1988; Hudson, 1992; McCallum & Dobson, 1995; Holmes, 1996). In addition, habituated gorillas subjected to tourism in Rwanda and Uganda have exhibited behavioural changes. They now forage and sleep outside their traditional ranges and venture onto cultivated land, where the chance of contracting human infections is greater because of increased proximity to human habitations (Madden, 1998; Homsy, 1999; J.M. Sleeman, pers. comm.).

Sources of disease exposure

Tourists

Travellers, both local and international, can bring novel strains of pathogens to an area, but may show few clinical signs of disease (Adams *et al.*, 1999, 2001). In addition, clinical signs may be modified or suppressed by medication and therefore hard to detect. Long flights, unfamiliar diets and climatic conditions, and changes of biorhythm and sleep pattern may stress tourists, and they may also be immuno-suppressed by medication or disease (Wilson, 1995; Ostroff & Kozarsky, 1998). As a result, shortly after arrival visitors from overseas often suffer from locally acquired intestinal infections, which may be introduced into the apes' habitat. Visitors have often paid large sums of money to view the apes and may therefore be unwilling to reveal that they are ill. A recent self-reported medical history survey carried out on visitors to the habituated chimpanzees in Kibale National Park, Uganda, indicated a high prevalence of the clinical signs of overt disease, especially diarrhoea, and several ongoing infections. Few visitors had current vaccinations. A concurrent survey of local residents revealed a similar situation, with predominant signs of respiratory disease (Adams *et al.*, 2001).

Researchers and managers

Persons engaged in research or management of habituated great apes must obey an even stricter hygiene protocol than tourists, because increased frequency and/or duration of contact with the apes puts researchers and managers at greater risk of infecting or being infected by the apes. *Herpesvirus hominis* and common respiratory viruses are likely to be transmitted by researchers (Ott-Joslin, 1993).

Guides and guards

Guides and guards are in daily contact with tourists and their potential pathogens as well as having contact

with many indigenous pathogens, to some of which they may themselves be resistant. These staff and their families rarely have the benefit of vaccination or medical care. Some guides remain in contact with ape groups long after the tourists have departed so that the groups can be readily located the next morning. Training guides in the enforcement of hygiene regulations and providing them and their families with good preventive medical care are thus of paramount importance.

Unintentional human contacts

Of the humans that come in contact with free-living apes, least control can be exerted over villagers, poachers, prospectors, miners, loggers, forest-product gatherers, and in areas of political unrest, refugees, aid workers, soldiers and bandits. Any of these people may carry a multiplicity of potential diseases that can threaten populations of apes (Islam *et al.*, 1995; Wallis & Lee, 1999; Adams *et al.*, 2001). In the case of refugees, the disease risks are exacerbated by over-crowding, exposure to the elements, poor sanitation and malnutrition. In the buffer zone of the Kahuzi-Biega National Park, Democratic Republic of Congo (DRC), the frequency of infection with *Entamoeba* spp. and *Giardia* sp. was, respectively, three times and 10 times greater in humans than in the sympatric gorillas (Eilenberger, 1997). Contamination of the environment by the excretions of large numbers of sick and destitute refugees has obvious implications for the health and survival of great ape populations in areas where they and refugees coexist.

Pathogens and disease transmission

The infectious agents that could potentially spread to the great apes from humans and, to a lesser extent, that could present a threat to humans, can be categorized according to their mode of transmission.

Aerosol/inhalation transmission

Diseases transmitted by aerosol (coughs and sneezes), sputum (spitting) and nasal discharges include the viruses of the common cold and influenza, the viral infections of human childhood (poliomyelitis, mumps, measles and chicken pox), and the bacilli of *Mycobacterium tuberculosis* (White *et al.*, 1972; Myers *et al.*, 1987; Wolfe *et al.*, 1998). The risk of aerosol-inhalation infection is directly proportional to the closeness of contact. Coughing, sneezing and spitting can all project infectious aerosols several metres (Thomson & Aberd, 1916; Habel, 1945). Tissue handkerchiefs are an attraction to young apes and, when discarded, will frequently be snatched up and eaten (M. Woodford, pers. obs.).

The ultraviolet component of direct sunlight will kill *M. tuberculosis* in 20–30 hours (Brack, 1987), but cultures maintained at 37°C have been found to be viable and infective after 12 years when protected from sunlight (Chadwick, 1982). In the dim light of the apes' damp forest environment *M. tuberculosis* might survive for a considerable time.

Five chimpanzees died of suspected pneumonia in Kasakela Community, Gombe National Park, Tanzania in 1968 (Goodall, 1986), and a further nine died from a similar disease in 1987 (Wallis & Lee, 1999). In 1996 a respiratory disease killed at least 11 chimpanzees at Mitumba Community, Gombe (Wallis & Lee, 1999); these apes rarely approached the local villages and the only humans that had close contact with them were the researchers and park personnel. A respiratory disease, possibly influenza of human origin, killed at least 11 chimpanzees in Mahale Mountains National Park, Tanzania, in September 1993 (Hosaka, 1995). There was no human influenza epidemic amongst the park's residents, but tourists visiting the chimpanzees at the time were observed to suffer from heavy colds and may have been the source of infection (Hosaka, 1995).

In a 32-year period 42 chimpanzees at Gombe National Park either died or were crippled, apparently as a result of outbreaks of transmissible diseases, some of which affected their human contacts simultaneously, and all of which were potentially infectious for both apes and humans (Butynski, 2001). Although no specimens were taken in any of these outbreaks, and no firm diagnoses were made, these infections could have been introduced by the researchers, the local attendants or the foreign tourists. Regardless of the source of infection, the deaths and sickness of so many animals caused considerable social disruption in this chimpanzee community, and affected a 35-year-old research project and the tourism programme at Gombe National Park.

In 1988, in the Virunga Volcanoes (Rwanda, Uganda and DRC), six female gorillas died of respiratory illness and 27 other cases were treated with penicillin injections. This illness occurred in three of the four tourist-habituated groups and in one of the three research-habituated groups. Eighty-one per cent of the apes in the affected groups showed signs of sickness, suggesting that the disease may have been new to this population. Serological and pathological evidence for measles virus in one gorilla suggested that measles or a related morbillivirus was responsible (Sholley & Hastings, 1989; Byers & Hastings, 1991). As a result, tighter controls on the health of tourists, guides and researchers entering the park were implemented, and 65 gorillas in the seven habituated groups were vaccinated by dart-gun injection against measles. No further signs of respiratory disease were seen after the initiation of the vaccination

campaign, and the disease did not spread to any other groups. Disease or mortality on this scale had not been recorded in the previous 21 years that these gorillas were under study (Sholley & Hastings, 1989; Byers & Hastings, 1991; Hastings *et al.*, 1991).

In 1990 bronchopneumonia affected 26 of 35 gorillas in a tourist-habituated group in the Virunga Volcanoes, resulting in the death of two animals (Macfie, 1991). In chimpanzees, pneumococcal pneumonia often follows infection with parainfluenza type 3 virus (Jones *et al.*, 1984), respiratory syncytial virus or influenza viruses, all of which can be transmitted to the apes by infected humans. Similarly, captive apes in zoos in North America and Europe often contract bacterial infections following initial infections with human respiratory viruses (Janssen, 1993).

Serological studies on free-ranging orang-utans not exposed to humans showed that these animals did not have antibodies against common human respiratory viruses, such as influenza and parainfluenza, but most orang-utans that had been exposed to humans were infected with these pathogens (Kilbourn *et al.*, 1998).

Faecal/oral transmission

Pathogens transmitted by the faecal/oral route include several bacterial organisms that cause diarrhoea (*Campylobacter* spp., *Shigella* sp. and *Salmonella* sp.), viruses, such as hepatitis A and B and poliomyelitis, and a number of protozoa (*Cryptosporidium* sp., *Cyclospora* sp., *Entamoeba* spp. and *Giardia* sp.) and parasitic worms that cause intestinal infections (Ashford *et al.*, 1990; Bakar *et al.*, 1991; Cooper, 1996; Smith *et al.*, 1996; Graczyk *et al.*, 1999; Nizeyi *et al.*, 1999; Nizeyi *et al.*, 2001). These infections are acquired through contact with infected faeces, and humans are at risk if they come into contact with ape faeces. If infected humans defaecate or vomit in the apes' habitat, particularly if within sight of the apes, there is potential for the introduction of these pathogens, all of which could cause serious disease and mortality in great apes (Benirschke & Adams, 1980; Janssen, 1993; Paul-Murphy, 1993; Swenson, 1993). Coprophagy may enhance faecal/oral transmission of intestinal parasites (Graczyk & Cranfield, 2001).

The larval stages of hookworms, *Necator* sp. of humans and *Ancylostomum* spp. of animals, which live in faeces-contaminated soil, can penetrate unbroken skin. Human hookworms *Necator americanus* may have caused the death of a gorilla in the Volcanoes National Park, Rwanda (Fossey, 1983). Another hookworm, *Ancylostoma duodenale*, was recovered on postmortem examination from a chimpanzee in Ibadan Zoo, Nigeria (Cousins, 1990). The Batwa people in the Bwindi-Impenetrable National Park, Uganda, are infected with hookworms

in a habitat that they share with gorillas (Ashford *et al.*, 1996). A study in Gombe National Park showed that the number of parasite species isolated from chimpanzees and olive baboons *Papio anubis* was greatest in the groups that had the most contact with humans (Nutter *et al.*, 1993).

In 1966, at Kasakela Community, Gombe, an outbreak of a paralytic disease, probably poliomyelitis, killed six chimpanzees and crippled six others. Three other chimpanzees disappeared at that time and were presumed to have also died from polio. Oral polio vaccine was given to the surviving chimpanzees. No samples were taken at the time and it can only be surmised that the source of the infection was the concurrent poliomyelitis epidemic in the local human population (Goodall, 1983, 1986).

Two years earlier there was a similar outbreak of paralytic disease among wild chimpanzees at Beni in eastern DRC. Seven individuals in a group of 48 were afflicted by a limb paresis, thought to have been caused by polio infection (Kortlandt, 1996). Although most visitors and researchers would have been immunised against polio, the villagers, guides, guards and illegal intruders would probably not have been. An additional concern is that oral polio vaccine can result in the shedding of viable poliovirus in faeces for periods of up to 30 days (Jong, 1995).

Indirect routes of transmission

A number of infectious diseases are transmitted by biting insects, intermediate hosts, or transferred on living or inanimate objects. Common cold and influenza viruses are easily transferred by contact with contaminated objects discarded in the environment. Boots, which are difficult to disinfect, have been known to spread infectious diseases.

Vector-borne diseases, such as malaria, filariasis and a wide range of arboviruses, require arthropods for their transmission. Young orang-utans kept in close proximity to humans are commonly infected with human malaria, transmitted by mosquitoes, whereas wild orang-utans are infected with only two species of malarial parasites, neither of which infect humans (Kilbourn *et al.*, 1998). Most of the arboviruses, such as dengue fever and yellow fever, have complex cycles involving a range of host species, including mammals, birds and biting arthropods. Human disturbance of habitats can create better conditions for vectors, allowing them to increase in abundance, or may introduce them into new areas; with these new vectors may come new viruses or viral strains.

The clinical signs of yaws, a debilitating disease caused by the human pathogen *Treponema pertunue*, have been observed frequently in gorillas in western

Central Africa (Cousins, 1972). This disease is most easily spread by direct contact, but non-biting flies can also transfer the causal organism from individuals with active lesions to superficial skin wounds on other individuals (Brack, 1987). Yaws is endemic in the human population in some parts of Africa (Widy-Wirsky, 1985), and transmission by flies from humans to apes, and vice-versa, is probable.

The influence of stress

Ecosystems are being fragmented, disrupted, restricted and increasingly utilised by people, and these disturbances could cause stress to the great apes. Stress may facilitate the transmission of disease and the consequent development of more pathogenic strains of diseases (May, 1988; Rossiter, 1990; Holmes, 1996). Habituation is likely to cause stress in apes, although it is not known to what extent this occurs or whether the level of stress reduces as the habituation progresses. However, chronic stress can lead to a number of immunological, gastrointestinal and cardiovascular changes that may alter susceptibility to diseases (von Holst, 1988), including those contracted from humans and those already carried by the apes, such as common parasites and viral infections (Butynski & Kalina, 1998; Butynski, 2001). In addition, the parasite burdens of habituated groups might be unnaturally high; in the Bwindi Impenetrable National Park parasite burdens were found to be higher in habituated gorillas than in unhabituated gorillas (Kalema, 1995).

A disease that appears to be exacerbated by stress is sarcoptic mange (scabies) (Graczyk *et al.*, 2001), a parasitic skin infection that resulted in the death of one young gorilla during an outbreak of the disease in a habituated group in Bwindi Impenetrable National Park (Macfie, 1996). The source of the infection was not confirmed, but scabies is endemic in the local human population (Kalema *et al.*, 1998). Another potential example is an alpha herpes virus that is known to infect more than 50% of the gorillas in the Virunga Volcanoes (Eberle, 1992; Eberle & Hilliard, 1995). At present this infection is subclinical, but it could become patent if the animals were under stress. Most of the gorillas in the Virunga Volcanoes are also infected with the intestinal parasitic worm *Oesophagostomum stephanostomum*. This worm is said to have been responsible for the deaths of many apes in zoos during the 1950s and 60s, when standards of care were lower than today and the apes were assumed to be stressed (Cousins, 1972). The possible effects of the stress of repeated close human contact on habituated great apes warrant further investigation (Butynski & Kalina, 1998; Butynski, 2001).

Discussion

The increasing popularity of ape-based tourism, and the long-term presence of researchers, park staff and local people within the range of habituated apes, are likely to increase the potential for the transmission of pathogens. Many tourists come into close proximity with habituated apes whilst exhibiting the clinical signs of potentially serious infectious diseases, and few are adequately vaccinated (Adams *et al.*, 2001).

Adherence to the existing regulations for visiting the great apes would greatly reduce the risk of disease transmission between humans and apes. Unfortunately, in spite of training courses for guards and guides, and the provision of information leaflets for visitors, there are many reports of contravention of the rules by both tourists and their official escorts (Butynski & Kalina, 1998; Adams *et al.*, 1999, 2001; Butynski, 2001; G. Kalema, pers. comm.). In the case of gorillas, these include:

- Exceeding the maximum allowed tourist group size for viewing gorillas (usually 6–8, but groups of up to at least 32 have visited gorillas).
- Exceeding the maximum of one tourist visit to a gorilla group in a single day.
- Approaching closer than the permitted 5 m (7 m is now recommended), and making physical contact with the gorillas.
- Staying with the gorillas for more than the permitted 1 hour.
- Defecation, vomiting, spitting and smoking within sight of gorillas.
- Discarding used tissues, cigarette ends, film cartons, banana skins and other debris in the gorillas' habitat.
- Using an electronic flash for taking photographs.
- Visits by children younger than 15 years.
- Visits by people who are obviously ill.
- Disregard of the regulations by military escorts.
- Park officials not checking childrens' ages or the health status of tourists when tour vehicle drivers collect permits.

While these are particular problems in the case of gorilla-based tourism, the findings of Adams *et al.* (1999, 2001) indicate that habituated chimpanzees are similarly threatened. Data on disease transmission and inter-species contact between humans and orang-utans are limited because habituation of free-ranging orang-utans for research and tourism is not as widespread as it is for gorillas and chimpanzees. Disease transmission does occur when orang-utans are habituated for rehabilitation and release programmes, but these are not the subject of this paper. We suggest that the following recommendations should be considered if the risks of disease transmission to great apes are to be reduced:

- Before the tourists reach the national park they should be made aware of the regulations for visiting, and the disease risks for the apes. The provision of facemasks would emphasise the latter point.
- Rewards, in excess of tourist tips, should be offered to guards and guides for diligently enforcing the rules.
- Information about local outbreaks of disease should be obtained from local health authorities.
- Researchers and relevant park and project staff should be appropriately vaccinated and free from gastro-intestinal parasites. Vaccinations should include tuberculosis, measles, mumps, rubella, yellow fever and polio (killed injectable vaccine only).
- Researchers, guards and guides should be tested annually for TB if they are not vaccinated (vaccination can produce false positive test results).
- Faeces, vomit and other debris should be removed in disposable containers, or buried at least 50 cm deep if deposited in the apes' habitat.
- The frequency of ranger patrols around the apes' habitats should be increased to reduce illegal entries.
- Autopsies should be performed on dead apes whenever possible, but only by veterinarians or other trained personnel who have access to protective clothing, facemasks, rubber gloves, disinfectants and equipment for specimen preservation and storage.
- Guards, guides and other local people should be made aware of the dangers of handling, butchering and eating the flesh of dead apes.
- All tourists proposing to visit habituated great apes should be required to undergo health screening and to produce an up-to-date vaccination certificate.

These recommendations represent a 'best practice' scenario. Tourists and others who visit habituated apes often have the potential to introduce serious infectious diseases. It would seem that it is only a matter of time before an introduced disease, such as paralytic poliomyelitis, pneumonia, measles or tuberculosis, enters and devastates a population of habituated apes. When this occurs there will no doubt be much debate on the relative benefits derived from tourism and the risks of further endangering the existence of ape populations through the introduction of disease.

Acknowledgements

Zoo Atlanta, The National Museums of Kenya, and the IUCN Eastern Africa Regional Office generously supported Tom Butynski during the writing of this paper.

References

- Adams, H.R., Sleeman, J. & New, J.C. (1999) A medical survey of tourists visiting Kibale National Park, Uganda, to determine the potential risk for disease transmission to chimpanzees (*Pan troglodytes*) from ecotourism. In *Proceedings of the American Association of Zoo Veterinarians 1999* (ed. C.K. Baer), pp. 270–271. American Association of Zoo Veterinarians, Media, Philadelphia, USA.
- Adams, H.R., Sleeman, J., Rwego, I. & New, J.C. (2001) Self-reported medical history survey of humans as a measure of health risk to chimpanzees (*Pan troglodytes schweinfurthii*) of Kibale National Park, Uganda. *Oryx*, **35**, 308–312.
- Alexander, K.A. & Appel, M.J.G. (1994) African wild dogs (*Lycan pictus*) endangered by a canine distemper epizootic among domestic dogs near the Masai Mara National Reserve, Kenya. *Journal of Wildlife Diseases*, **30**, 481–485.
- Amman, K. (2001) Bushmeat hunting and the great apes. In *Great Apes and Humans: The Ethics of Coexistence* (eds B.B. Beck, T.S. Stoinski, M. Hutchins, T.L. Maple, B. Norton, A. Rowan, E.F. Stevens & A. Arluke), pp. 57–70. Smithsonian Institution Press, Washington DC, USA.
- Ashford, R.W., Reid, G.D.F. & Butynski, T.M. (1990) The intestinal faunas of man and mountain gorillas in a shared habitat. *Annals of Tropical Medicine and Parasitology*, **84**, 337–340.
- Ashford, R.W., Lawson, H., Butynski, T.M. & Reid, G.D.F. (1996) Patterns of intestinal parasitism in the mountain gorilla (*Gorilla gorilla*) in the Bwindi-Impenetrable Forest, Uganda. *Journal of Zoology* (London), **239**, 507–514.
- Bakar, M.I., Gbakima, A.A. & Bah, Z. (1991) Intestinal helminth parasites in free-living monkeys from a West African rain forest. *African Journal of Ecology*, **29**, 170.
- Benirschke, K. & Adams, F.D. (1980) Gorilla diseases and causes of death. *Journal of Reproduction and Fertility* (Supplement), **28**, 139–148.
- Brack, M. (1987) *Agents Transmissible from Simians to Man*. Springer-Verlag, Berlin, Germany.
- Butynski, T.M. (2001) Africa's great apes. In *Great Apes and Humans: The Ethics of Coexistence* (eds B.B. Beck, T.S. Stoinski, M. Hutchins, T.L. Maple, B. Norton, A. Rowan, E.F. Stevens & A. Arluke), pp. 3–56. Smithsonian Institution Press, Washington DC, USA.
- Butynski, T.M. & Kalina, J. (1998) Gorilla tourism: a critical look. In *Conservation of Biological Resources* (eds E.J. Milner-Gulland & R. Mace), pp. 280–300. Blackwell Science, Oxford, UK.
- Byers, A.C. & Hastings, B. (1991) Mountain gorilla mortality and climatic factors in the Parc National des Volcans, Ruhengeri Prefecture, Rwanda, 1988. *Mountain Research and Development*, **2**, 145–151.
- Chadwick, V. (1982) *Mycobacteria*. Wright & Sons, Bristol, UK.
- Cooper, J.E. (1996) Parasites and pathogens of non-human primates. *The Veterinary Record*, **139**, 48.
- Cousins, D. (1972) Diseases and injuries in wild and captive gorillas (*Gorilla gorilla*). *International Zoo Yearbook*, **12**, 211–218.
- Cousins, D. (1990) *The Magnificent Gorilla*. The Book Guild, Sussex, UK.
- Eberle, R. (1992) Evidence for an alpha-herpes virus indigenous to mountain gorillas. *Journal of Medical Primatology*, **21**, 246–251.
- Eberle, R. & Hilliard, J. (1995) The simian herpesviruses. *Infectious Agents and Disease*, **4**, 55–70.

- Eilenberger, U. (1997) Endoparasites in gorillas and humans in the same habitat. *Gorilla Journal*, **15**, 11–14.
- Fossey, D. (1983) *Gorillas in the Mist*. Houghton Mifflin, Boston, USA.
- Goodall, J. (1971) *In the Shadow of Man*. Houghton Mifflin, Boston, USA.
- Goodall, J. (1983) Population dynamics during a fifteen-year period in one community of free-living chimpanzees in the Gombe Stream National Park, Tanzania. *Zeitschrift für Tierpsychologie*, **61**, 1–60.
- Goodall, J. (1986) *The Chimpanzees of Gombe: Patterns of Behaviour*. Harvard University Press, Cambridge, USA.
- Graczyk, T.K. & Cranfield, M.R. (2001) Coprophagy and intestinal parasites: implications to human-habituated mountain gorillas (*Gorilla gorilla beringei*). *Recent Research Developments in Microbiology*, **5**, 285–293.
- Graczyk, T.K., Lowenstine, L.J. & Cranfield, M.R. (1999) *Capillaria hepatica* (Nematoda) infections in human-habituated gorillas (*Gorilla gorilla beringei*) of the Parc National de Volcans, Rwanda. *Journal of Parasitology*, **85**, 1168–1170.
- Graczyk, T.K., Mudakikwa, A.B., Eilenberger, U. & Cranfield, M.R. (2001) Hyperkeratotic mange caused by *Sarcoptes scabiei* (Acariformes: Sarcoptidae) in juvenile human-habituated mountain gorillas (*Gorilla gorilla beringei*). *Parasitology Research*, **87**, 1024–1028.
- Groves, C.P. (2001) *Primate Taxonomy*. Smithsonian Institution Press, Washington DC, USA.
- Habel, K. (1945) Mumps and chickenpox as air-borne diseases. *American Journal of Medical Science*, **209**, 75–78.
- Hastings, B.E., Kenny, D., Lowenstine, L.J. & Foster, J.W. (1991) Mountain gorillas and measles: ontogeny of a wildlife vaccination program. *Proceedings of AAZV Conference (September/October 1991)* (ed. R.E. Junge), pp. 198–205. American Association of Zoo Veterinarians, Media, Philadelphia, USA.
- Hilton-Taylor, C. (compiler) (2000) *2000 IUCN Red List of Threatened Species*. IUCN, Gland, Switzerland.
- Holmes, J.C. (1996) Parasites as threats to biodiversity in shrinking ecosystems. *Biodiversity and Conservation*, **5**, 957–983.
- Homsy, J. (1999) *Ape Tourism and Human Diseases: How Close Should we Get? A Critical Review of the Rules and Regulations Governing Park Management and Tourism for the Wild Mountain Gorilla* (*Gorilla gorilla beringei*). Unpublished report, International Gorilla Conservation Programme, Nairobi, Kenya.
- Hosaka, K. (1995) Epidemics and wild chimpanzee study groups. *Pan Africa News*, **2**, 1–4.
- Hudson, H.R. (1992) The relationship between stress and disease in orphan gorillas and its significance for gorilla tourism. *Gorilla Conservation News*, **6**, 8–10.
- Islam, M.S., Siddique, A.K.M., Salam, A., Akram, K., Majamdar, R.N., Zaman, K., Fronczak, N. & Laston, S. (1995) Microbiological investigation of diarrhoea epidemics among Rwandan refugees in Zaire. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **89**, 506.
- Janssen, D.L. (1993) Diseases of great apes. In *Zoo and Wild Animal Medicine: Current Therapy*, 3 (ed. M.E. Fowler), pp. 334–338. W.B. Saunders Co., Philadelphia, USA.
- Jones, E.E., Alford, P.L., Reingold, A.L., Russell, H., Keeling, M.E. & Broome, C.V. (1984) Predisposition to invasive pneumococcal illness following parainfluenza type 3 infection in chimpanzees. *Journal of the American Veterinary Medical Association*, **185**, 1351–1353.
- Jong, E.C. (1995) Immunizations. In *The Travel and Tropical Medicine Manual*, 2nd edn (eds E.C. Jong & R. McMullen), pp. 28–49. W.B. Saunders, Philadelphia, USA.
- Kalema, G. (1995) Epidemiology of the intestinal parasite burden of mountain gorillas in Bwindi Impenetrable National Park, S.W. Uganda. *Zebra Foundation, British Veterinary Zoological Society Newsletter*, Autumn, pp. 18–34.
- Kalema, G. & Cooper, J.E. (1996) Veterinary involvement with the mountain gorillas in Uganda and Rwanda. *Newsletter of the World Association of Wildlife Veterinarians*, **5**, 4–5.
- Kalema, G., Kock, R. & Macfie, E. (1998) An outbreak of sarcoptic mange in free-ranging mountain gorillas (*Gorilla gorilla beringei*) in Bwindi Impenetrable National Park, South Western Uganda. In *Proceedings of the American Association of Zoo Veterinarians/American Association of Wildlife Veterinarians, Joint Conference* (ed. C.K. Baer), p. 438. American Association of Zoo Veterinarians, Media, Philadelphia, USA.
- Kalina, J. & Butynski, T.M. (1995) Close encounters between people and gorillas. *African Primates*, **1**, 20.
- Kalter, S.S. (1980) Infectious diseases of the great apes of Africa. *Journal of Reproduction and Fertility* (Supplement), **28**, 149–159.
- Kalter, S.S. (1986) Overview of simian viruses and recognised virus diseases and laboratory support for the diagnosis of viral infections. In *Primates: The Road to Self-Sustaining Populations* (ed. K. Benirschke), pp. 681–709. Springer-Verlag, New York, USA.
- Karesh, W.B. (1995) Wildlife rehabilitation: additional considerations for developing countries. *Journal of Zoo and Wildlife Medicine*, **26**, 2–9.
- Kilbourn, A.M., Karesh, W.B., Bosi, E.J., Cook, R.A., Andau, M. & Wolfe, N.D. (1998) Disease evaluation of free-ranging orangutans (*Pongo pygmaeus pygmaeus*) in Sabah, Malaysia. In *Proceedings of the American Association of Zoo Veterinarians and American Association of Wildlife Veterinarians Joint Conference* (ed. C.K. Baer), pp. 417–421. American Association of Zoo Veterinarians, Media, Philadelphia, USA.
- Kortlandt, A. (1996) An epidemic of limb paresis (polio?) among the chimpanzee population at Beni (Zaire) in 1964, possibly transmitted by humans. *Pan Africa News*, **3**, 9–10.
- Macfie, L. (1991) The Volcanoes Veterinary Center. *Gorilla Conservation News*, **5**, 21.
- Macfie, L. (1996) Case report on scabies infection in Bwindi gorillas. *Gorilla Journal*, **13**, 19–20.
- Madden, F. (1998) *The Problem Gorilla*. Unpublished Report, International Gorilla Conservation Programme, Nairobi, Kenya.
- May, R.M. (1988) Conservation and disease. *Conservation Biology*, **2**, 28–30.
- McCallum, H. & Dobson, A. (1995) Detecting disease and parasite threats to endangered species and ecosystems. *Trends in Ecology and Evolution*, **10**, 190–194.
- McGrew, W.C., Tutin, C.E.G., Collins, D.A. & File, S.K. (1989) Intestinal parasites of sympatric *Pan troglodytes* and *Papio* spp. at two sites: Gombe, Tanzania and Mount Assirik, Senegal. *American Journal of Primatology*, **17**, 147–155.
- Meder, A. (1994) Causes of death and diseases of gorillas in the wild. *Gorilla Journal*, **2**, 19–20.
- Murray, S. (1990) *Intestinal parasites of baboons and chimpanzees in Gombe National Park*. Senior Thesis, Tufts University School of Veterinary Medicine, North Grafton, Massachusetts, USA.

- Myers, M.G., Kramer, L.W. & Stanberry, L.R. (1987) Varicella in a gorilla. *Journal of Medical Virology*, **23**, 317–322.
- Nizeyi, J.B., Innocent, R.B., Erume, J., Kalema, G.R.N.N., Cranfield, M.R. & Graczk, T.K. (2001) Campylobacteriosis, salmonellosis and shigellosis in free-ranging human-habituated mountain gorillas of Uganda. *Journal of Wildlife Diseases*, **37**, 239–244.
- Nizeyi, J.B., Mwebe, R., Nanteza, A., Cranfield, M.R., Kalema, G.R.N.N. & Graczk, T.K. (1999) *Cryptosporidium* sp. and *Giardia* sp. infections in mountain gorillas (*Gorilla gorilla beringei*) of the Bwindi Impenetrable National Park, Uganda. *Journal of Parasitology*, **85**, 1084–1088.
- Nutter, F., Stem, C. & Goodall, J. (1993) A comparison of gastrointestinal parasites in two communities of chimpanzees at Gombe National Park. A preliminary study of the inter-relationships of parasitic disease. Second instalment, Tufts University School of Veterinary Medicine, North Grafton, Massachusetts, USA.
- Ostroff, S.M. & Kozarsky, P. (1998) Emerging infectious diseases and travel medicine. *Infectious Disease Clinics of North America*, **12**, 231–241.
- Ott-Joslin, J.E. (1993) Zoonotic diseases of nonhuman primates. In *Zoo and Wild Animal Medicine: Current Therapy 3* (ed. M.E. Fowler), pp. 358–373. W.B. Saunders, Philadelphia, USA.
- Paul-Murphy, J. (1993) Bacterial enterocolitis in nonhuman primates. In *Zoo and Wild Animal Medicine: Current Therapy 3* (ed. M.E. Fowler), pp. 344–353. W.B. Saunders, Philadelphia, USA.
- Rijksen, H.D. (2001) The orangutan and the conservation battle in Indonesia. In *Great Apes and Humans: The Ethics of Coexistence* (eds B.B. Beck, T.S. Stoinski, M. Hutchins, T.L. Maple, B. Norton, A. Rowan, E.F. Stevens & A. Arluke), pp. 57–70. Smithsonian Institution Press, Washington DC, USA.
- Roelke-Parker, M.E., Munson, L., Packer, C., Kock, R., Cleaveland, S., Carpenter, M., O'Brien, S.J., Pospichil, A., Hofmann-Lehmann, R., Lutz, H., Mwamengele, G.L.M., Mgas, M.N., Machange, G.A., Summers, B.A. & Appel, M.J.G. (1996) A canine distemper virus epidemic in Serengeti lions (*Panthera leo*). *Nature*, **379**, 441–445.
- Rossiter, P.B. (1990) The increased risk of infectious disease with intensive utilisation of wildlife. In *Wildlife Research for Sustainable Development* (eds J.G. Grootenhuis, S.G. Njuguna & P.W. Kat), pp. 124–136. Kenya Agricultural Research Institute/Kenya Wildlife Service/National Museums of Kenya, Nairobi.
- Sholley, C. (1989) Mountain gorilla update. *Oryx*, **23**, 57–58.
- Sholley, C. & Hastings, B. (1989) Outbreak of illness among Rwanda's gorillas. *Gorilla Conservation News*, **3**, 7.
- Sleeman, J.M., Meader, L.L., Mudakikwa, A.B., Foster, J.W. & Patton, S. (2000) Gastro-intestinal parasites of mountain gorillas (*Gorilla gorilla beringei*) from the Parc National des Volcans, Rwanda. *Journal of Zoo and Wildlife Medicine*, **31**, 322–328.
- Smith, H.V., Paton, C.A., Girdwood, R.W.A. & Mtambo, M.M.A. (1996) *Cyclospora* in non-human primates in Gombe, Tanzania. *The Veterinary Record*, **May 25**, 528.
- Swenson, R.B. (1993) Protozoa parasites of great apes. In *Zoo and Wild Animal Medicine: Current Therapy 3* (ed. M.E. Fowler), pp. 352–355. W.B. Saunders, Philadelphia, USA.
- Thomson, F.H. & Aberd, C.M. (1916) The aerial conveyance of infection. *Lancet*, **1**, 341–344.
- Toft, J.D. (1986) The pathoparasitology of nonhuman primates: a review. In *Primates: The Road to Self-Sustaining Populations* (ed. K. Benirschke), pp. 571–679. Springer-Verlag, New York, USA.
- Von Holst, D. (1988) The concept of stress and its relevance for animal behaviour. *Advances in the Study of Behaviour*, **27**, 1–131.
- Wallis, J. & Lee, D.R. (1999) Primate conservation: the prevention of disease transmission. *International Journal of Primatology*, **20**, 803–826.
- White, R.J., Simmons, L. & Wilson, R.B. (1972) Chickenpox in young anthropoid apes: clinical and laboratory findings. *Journal of the American Veterinary Medical Association*, **161**, 690–692.
- Widy-Wirsky, R. (1985) Surveillance and control of resurgent yaws in the African region. *Reviews of Infectious Diseases*, **7** (Supplement 2), 227–232.
- Wilkie, D.S. (2001) Bushmeat trade in the Congo Basin. In *Great Apes and Humans: Ethics of Coexistence* (eds B.B. Beck, T.S. Stoinski, M. Hutchins, T.L. Maple, B. Norton, A. Rowan, E.F. Stevens & A. Arluke), pp. 86–109. Smithsonian Institution Press, Washington DC, USA.
- Wilson, M.E. (1995) Travel and the emergence of infectious diseases. *Emerging Infectious Diseases*, **1**, 39–46.
- Wolfe, N.D., Escalante, A.A., Karesh, W.B., Kilbourn, A., Spielman, A. & Lal, A.A. (1998) Wild primate populations in emerging infectious disease research: the missing link? *Emerging Infectious Diseases*, **4**, 149–158.
- Wolfe, N.D., Kilbourn, A.M., Karesh, W.B., Rahman, H.A., Bosi, E.J., Cropp, B.C., Andau, M., Spielman, A. & Gruber, D. (2001) Sylvatic transmission of arboviruses among Bornean orangutans. *Journal of Tropical Medicine and Hygiene*, **64**, 310–316.
- Woodford, M.H. (1989) *Report to IUCN on a Visit to the Parc des Volcans, Rwanda*. Unpublished report.

Biographical sketches

Michael Woodford has recently retired from the Chairmanship of the IUCN/SSC Veterinary Specialist Group, a post that he held since its inception in the early 1980s. He is currently President of the Office International des Epizooties (OIE) Working Group on Wildlife Diseases. He has worked on diseases of wildlife in many countries.

Thomas M. Butynski is the Senior Conservation Biologist for Zoo Atlanta's Africa Biodiversity Conservation Program, Vice-Chair of the African Section of the IUCN/SSC Primate Specialist Group and Senior Editor of *African Primates*. He is scientific advisor to the Dian Fossey Gorilla Fund International, The Primate Conservation & Welfare Society, and the AZA's Field Conservation Committee.

William Karesh heads the Field Veterinary Program of the Wildlife Conservation Society that has over 300 field projects in 50 countries around the world. He also serves as the co-chairman of the IUCN/SSC Veterinary Specialist Group and is a member of the Advisory Board for the Mountain Gorilla Conservation Fund.