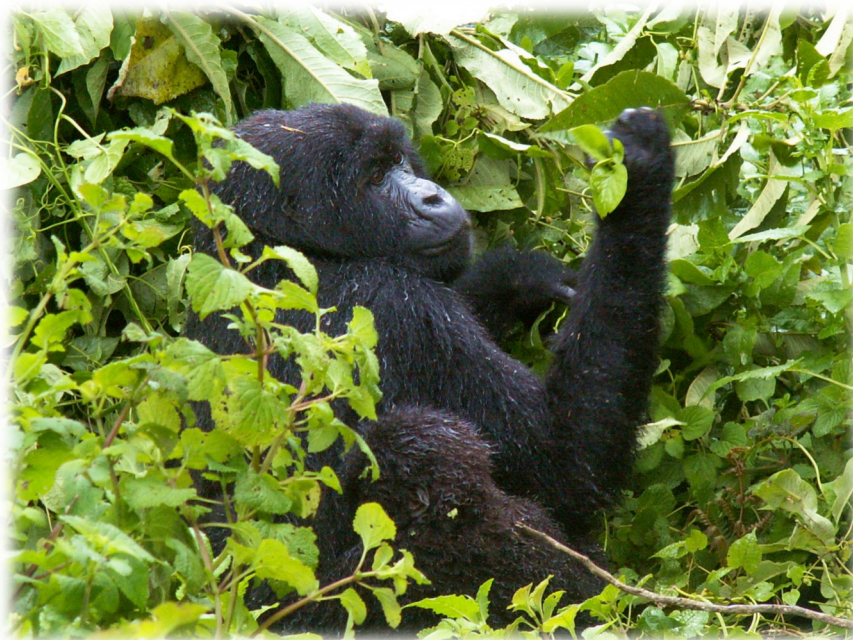




Sveriges lantbruksuniversitet
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Zoonotic Respiratory Infections and Great Ape Conservation – an Emerging Challenge

Cecilia Tegner



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Zoonotic Respiratory Infections and Great Ape Conservation – an Emerging Challenge

Respiratoriska zoonoser – en utmaning i bevarandet av människoaporna

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CONTENTS

ABSTRACT	1
SAMMANFATTNING	2
INTRODUCTION	3
METHODS	4
LITERATURE REVIEW	4
<i>Confirmed pathogens in respiratory disease outbreaks</i>	4
<i>Transmission and detection</i>	5
Health surveillance	6
<i>Preventive strategies</i>	6
Prevention through human health.....	7
Hygiene standards and visitor regulations	7
Intervention	8
DISCUSSION	9
<i>The knowledge gap</i>	9
<i>The impact of tourism</i>	10
<i>Interventions</i>	11
<i>Final remarks</i>	12
ACKNOWLEDGEMENTS	12
REFERENCES	13

ABSTRACT

The conservation of great apes faces many challenges, one of which is the threat of infectious disease outbreaks. Zoonotic transmission of respiratory diseases from humans to wild great apes has recently been confirmed. Since respiratory disease is one of the major causes of death in both gorillas and chimpanzees, this gives reason for major concern.

Little is known about the risks of disease transmission from humans to great apes in natural environments, and there is a need for systematic risk evaluation. Researchers, conservation staff and tourists spend time in very close proximity of wild great apes, sometimes during long time periods, which poses a potential risk of disease spillover. However, the presence of researchers and tourists has been shown to decrease the risk of poaching, making the matter increasingly complex. The risk of respiratory diseases of human origin affecting great apes can be minimized by hygienic rules and visitor regulations. Preventive measures can also be aimed directly at the apes through hands-on veterinary medicine. Direct intervention in wild populations through preventive or curative treatment is however a very controversial matter, since it risks interfering with evolutionary processes.

Conservation medicine is a multidisciplinary science that cannot be isolated from ecology, ethology, human medicine or social sciences. Neither can the health and disease of wild great apes be separated from the health and disease of humans in the same area. A scientific, interdisciplinary approach is necessary in the aim for a standardized, systematic strategy to disease prevention and surveillance in endangered great ape populations.

SAMMANFATTNING

Bevarandet av människoapor möter många utmaningar, bland annat risken för utbrott av infektiösa sjukdomar. Zoonotisk överföring av respiratoriska sjukdomar från människa till andra människoapor har nyligen bekräftats och är en anledning till oro, eftersom respiratorisk sjukdom är en av de främsta dödsorsakerna hos både gorillor och schimpanser i det vilda.

Idag är kunskapen om riskerna för överföring av infektiösa sjukdomar från människor till människoapor i naturliga miljöer bristfällig och det finns ett behov av systematisk riskbedömning. Turister, forskare och parkpersonal spenderar ibland lång tid i människoapornas habitat, vilket utgör en risk för zoonotisk smittoöverföring. Samtidigt har närvaro av turister och forskare visat sig verka skyddande mot tjuvjakt – vilket gör detta till en komplex fråga. Risken för att humana respiratoriska sjukdomar ska drabba människoapor kan minimeras genom hygienbestämmelser och restriktioner som omfattar alla personer som vistas i deras habitat. Förebyggande åtgärder kan även riktas direkt mot människoaporna genom veterinära åtgärder, såsom vaccinationer eller annan medicinsk behandling. Direkta interventioner i vilda populationer är dock mycket kontroversiella, då de riskerar att inverka på evolutionära processer.

Bevarandemedicin är en multidisciplinär vetenskap som inte kan särskiljas från studier inom ekologi, etologi, humanmedicin eller samhällsvetenskap. På samma sätt kan inte människoapornas hälsa särskiljas från hälsan hos de människor som lever och rör sig i samma områden. Ett vetenskapligt, interdisciplinärt angreppssätt är nödvändigt i strävan efter en standardiserad, systematisk strategi kring förebyggande arbete, hälsoövervakning och sjukdomsbekämpning i populationer av utrotningshotade människoapor.

INTRODUCTION

On the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, all great apes except humans are listed as endangered or critically endangered (IUCN, 2012). The great apes are: orang-utans (*Pongo* spp.), bonobos (*Pan paniscus*), chimpanzees (*Pan troglodytes*) and gorillas (*Gorilla* spp.). Chimpanzees and bonobos are most closely related to humans, but all great apes have very similar genetic makeup (Prüfer et al., 2012). Due to this phylogenetic relationship, pathogens risk being transmitted between species. Although some of these pathogens might be harmless to humans, they may pose a great threat to previously unexposed individuals and populations of primates (Ott-Joslin, 1993; Wallis and Lee, 1999; Ferber, 2000). On the other hand, infectious diseases that have emerged from non-human primates and caused outbreaks in humans have been studied quite extensively, for example in the cases of simian retroviruses (i.e. Calvignac-Spencer et al., 2012; Peeters and Delaporte, 2012; Rault, 2012).

Great ape conservation faces many challenges today, such as habitat fragmentation, deforestation, poaching and illegal trade with animals. However, disease – and respiratory disease in particular – is a major cause of death in many great ape populations (Cranfield, 2008; Williams et al., 2008). Leendertz et al. (2006) point out that even a few lethality can be detrimental for small, isolated populations. Furthermore, disease outbreaks can also have long-term negative effects on a population beyond the acute mortality. Ryan and Walsh (2011) describe recovery time as the total time a population suffers consequences of a disease outbreak, through effects on reproduction and behaviour. In their study, modelling showed that a single, low-mortality respiratory outbreak in gorillas has a recovery time of five years.

Humans and great apes coming into close contact during conservation efforts and tourism has long been feared to cause fatal respiratory disease outbreaks through the zoonotic transmission of human pathogens (Wallis and Lee, 1999; Ferber, 2000; Leendertz et al., 2006). This fear has recently been proven valid, as human viruses have been found in great ape populations (Kaur et al., 2008; Koendgen et al., 2008; Koendgen et al. 2010; Palacios et al., 2011).

This paper reviews the current knowledge about human-to-great ape respiratory disease transmission and prevention, by investigating which respiratory diseases could potentially be transmitted from humans to great apes, and if effective strategies are available to prevent this from happening. This leads up to a crucial question: can human presence in great habitats be justified by the positive outcomes of conservation efforts – or are we doing more harm than good?

METHODS

By using the databases Web of Knowledge, Scopus, CAB Abstracts and PubMed, the literature was searched for original articles and reviews about respiratory zoonoses in great apes. Search words included: *anthroponoses*, *zooanthroponoses*, *zoonoses*, *primate**, *great ape**, *conservation*, *disease transmission*, *respiratory*, *emerging*, *bonobo**, *gorilla**, *orangutan**, *orangutan**, and *chimpanzee**. Reference lists were also used to broaden and extend the search.

LITERATURE REVIEW

Historically, there have been many reports of respiratory outbreaks of unknown aetiology in African great ape populations, where humans have often been the suspected source of infection (Wallis and Lee, 1999; Woodford et al., 2002; Boesch, 2008; Hanamura et al., 2008; Williams et al., 2008). The human respiratory pathogens that are suspected to cause disease in great apes are bacteria such as: *Mycobacterium tuberculosis*, *Streptococcus pneumoniae* and other bacterial pneumonias; and viruses including: parainfluenza, influenza, paramyxo-, rhino-, adeno-, pertussis and rubella viruses (Ott-Joslin, 1993; Homsy, 1999; Loomis, 2003). Reported respiratory outbreaks at selected chimpanzee field sites are summarized in Appendix 1.

Confirmed pathogens in respiratory disease outbreaks

Respiratory disease is the main cause of death in wild, human-habituated chimpanzees (Woodford et al., 2002; Lonsdorf et al., 2006; Williams et al., 2008), and the second most common cause of death in mountain gorillas (Cranfield, 2008). However, the causative agent of great ape respiratory disease outbreaks has only been identified in four cases (Kaur et al., 2008; Koendgen et al., 2008; Koendgen et al., 2010; Palacios et al., 2011).

In 2008, the first direct evidence of virus transmission from humans to wild great apes was published (Koendgen et al., 2008). Two human paramyxoviruses – human respiratory syncytial virus (HRSV) and human metapneumovirus (HMPV) – were identified in chimpanzee respiratory outbreaks in Taï National Park, Côte d'Ivoire. Through phylogenetic analysis, it was shown that the strains clustered within clades of circulating human pandemic viruses. The proximate cause of death was bacterial pneumonia, something that both HMPV and HRSV predispose for (Wallis and Lee, 1999; Woodford et al., 2002). Two new *Streptococcus pneumoniae* strains were identified. The strains were more closely related to human strains than to each other, indicating human origin. However, a non-human source of the bacteria could not be ruled out. Koendgen et al. (2008) concluded that researchers – who spend up to eight hours per day with chimpanzee groups – were the most likely source of infection. Historically, chimpanzee group mortality correlates with the group's exposure to researchers. This researcher-exposure effect was shown most obviously during habituations, where great apes are made accustomed to human presence. Habituations are paramount to research and tourism, but also increase risk of disease transmission (Wallis and Lee, 1999; Woodford et al., 2002; Macfie and Williamson, 2010), since the habituation process likely poses the initial exposure to human pathogens in combination with stress.

Following two respiratory outbreaks in 2005 and 2006 in chimpanzee groups of Mahale Mountains National Park, Tanzania, investigations found that a human related chimpanzee strain of metapneumovirus (hrcMPV) was the causing agent of at least one of the outbreaks (Hanamura et al., 2008; Kaur et al., 2008). The strain was believed to be the same as that of a 2003 outbreak at Mahale and when analysed, the strain also showed 94 % identity to the strain from Tai, described above (Koendgen et al., 2008). Due to the epidemiological characteristics of the outbreaks, Kaur et al. (2008) fear that hrcMPV has become enzootic in Mahale since 2003, thus risking new fatal outbreaks being caused in naïve groups due to migration of infected chimpanzees.

Humans are the only known reservoir for HRSV and HMPV (Koendgen et al., 2008). The viruses are common sources of respiratory disease in humans and no vaccines are available (Ryan and Walsh, 2011). In captive environments, transmission of HRSV from humans to chimpanzees has been reported, as well as detection of antibodies against several other human pathogens (e.g. Szentiks et al., 2009; Schaumburg et al., 2012; Kooriyama et al., 2013). Kilbourn et al. (2003) compared levels of antibodies against selected viruses of Malaysian free-ranging orang-utans undergoing translocation, and semi-captive orang-utans housed at Sepilok Orangutan Rehabilitation Centre. It was found that the groups shared antibodies for 11 out of 47 viruses, but levels of exposure to some viruses differed markedly. The prevalence of antibodies against respiratory viruses was low, albeit higher in the semi-captive group, which could be attributed to human presence.

As well as in chimpanzees, HMPV has been detected in mountain gorillas. This was done in the Virunga National Park, Rwanda, after an outbreak in 2009 (Palacios et al., 2011). During the outbreak 11 out of 12 individuals in the group showed moderate to severe signs of illness. Due to the outbreak's severity, five individuals were given antimicrobial treatment. Two untreated individuals died: one adult female and one infant. Human-related isolates of HMPV were detected in several tissues and serum in the adult, and in the lungs of the infant.

Transmission and detection

Transmission of respiratory disease occurs through aerosol or droplets (Ott-Joslin, 1993) and some pathogens can stay infectious in the environment for a very long time, allowing indirect transmission (Homsy, 1999; Woodford et al., 2002). The rainforest, where the forest floor is damp and warm, without direct sunlight, is an ideal environment for microbial survival and transmission.

There are many difficulties in detecting and identifying respiratory pathogens in wild great apes. Many authors have pointed out that a knowledge gap exists concerning great ape health and disease (e.g. Homsy, 1999; Whittier et al., 2001; Leendertz et al., 2006), which is assigned to a few factors and circumstances. More specifically: field projects are often strictly observational, in remote locations. In these locations, veterinary personnel are often lacking, few diagnostic tests are available and both climate and scavengers make it difficult to perform post-mortem examinations and obtain good tissue samples. In addition to this, few non-invasive methods are available to screen for disease in live animals, and the behaviour of the species sometimes make it hard to observe the same individual continuously.

Health surveillance

Health surveillance programs are in place in many of the great ape conservation programs (Leendertz et al., 2006; Koendgen et al., 2008; Smiley et al., 2010). In Gombe National Park, Tanzania, behavioural data from chimpanzees has been recorded since the 1960's, and observation of health and disease has been included in ethograms from the start (Lonsdorf et al., 2006). However, recordings have differed depending on year and have sometimes been performed non-systematically. During the years of 2001-2003 chimpanzee health assessment was performed adhering to a systematic protocol, which was later modified to the one currently in use. It now includes information on behaviour, body condition, lameness, faecals and specific signs of respiratory illness.

Non-invasive methods are valuable tools in the screening of disease in wild animal populations. Faecal samples from great apes have been collected and used in analysis of intestinal flora, systemic diseases and parasites (e.g. Goldberg et al., 2007; Gillespie et al., 2008; Rwego et al., 2008). Moreover, faecals have recently been shown to be of use also to detect respiratory diseases in chimpanzees (Kaur et al., 2008; Koendgen et al., 2010). To assess the validity of faecal samples as a detection method for HMPV and HRSV in chimpanzees, Koendgen et al. (2010) compared samples from symptomatic and asymptomatic individuals; during and between HRSV and HMPV outbreaks, as well as during outbreaks with unknown aetiological agent. The study showed that faecal samples are good predictors of outbreak status, and sample results correlated strongly with observations of symptoms and behaviour. Interestingly, sequences from the confirmed HRSV outbreak (Koendgen et al., 2008) were identical to strains in faecal samples from an outbreak in Tai in 2005 with previously unknown aetiology. In mountain gorillas, methods have been developed for the collection of saliva from discarded food, preferably wild celery (Smiley et al., 2010). By collecting saliva, screening for pathogens can be performed and genetic analyses conducted. Saliva is useful for detecting pathogens that are not excreted in urine or faecals, which holds true for most respiratory viruses (Smiley et al., 2010).

Preventive strategies

In a review, Jefferson et al. (2008) examined the evidence for effectiveness of different preventive measures against respiratory virus transmission during human pandemics. They concluded that a cheap and effective way of reducing spread is implementing barriers, hygienic measures such as the wearing of gloves and facemasks, and isolating persons with suspected infection. The reviewed articles often describe that compliance with different preventive strategies is a problem. Therefore the authors argue that it is problematic to achieve compliance during long-term interventions.

There are two different – but not necessarily exclusive – approaches to the prevention of human-originated disease outbreaks in great apes (Deem et al., 2001; Ryan and Walsh, 2011). Either, the apes are the targets of the efforts in a hands-on approach, by preventing infection through vaccinations, or, if disease is a fact – treating the animals with available means. Alternatively, humans are the main targets of efforts in a hands-off approach, for example by

hygienic and behavioural restrictions, and through health programs for staff and researchers, including vaccinations (Cranfield, 2008; Boesch, 2008).

Prevention through human health

Possible human sources of zoonotic pathogens include local populations, poachers, tourists, researchers and conservation personnel, such as park rangers and guides (The Mountain Gorilla Veterinary Project 2002 Employee Health Group, 2004). Compliance with preventive measures is still a big problem at great ape field sites, with researchers and park personnel, as well as tourists (Wallis and Lee, 1999; Woodford et al., 2002; Lukasik-Braum and Spelman, 2008; Macfie and Williamson, 2010; Ryan and Walsh, 2011). At an orang-utan rehabilitation centre in Sepilok, Malaysia, a questionnaire concerning immune status and perceived disease symptoms was answered by visiting tourists (Muehlenbein et al., 2010), where 15 % of the tourists reported to experience signs of disease at the time of their visit. Studies at African great ape-tourism sites have unfortunately shown similar results (Macfie and Williamson, 2010).

The health status of researchers and conservation staff is especially important to monitor, since they come into very close proximity of great apes, sometimes for long periods of time. At Parc National des Volcans, Rwanda, an employee health program was initiated in 2001 with the goals of improving staff health and finding critical control points to minimize the risk of disease transmission (The Mountain Gorilla Veterinary Project 2002 Employee Health Group, 2004). In trying to find which parameters were of importance to health status, questions concerning staff's perceived health, in addition to work- and living situations, were included in the health check-up. Of the persons in the survey, 24% reported to have experienced disease symptoms within the past month. The most common symptoms were cough and fever – both characteristic of respiratory infections. Despite this, 80% of the staff reported that they had no absence from work due to illness in the past 6 months.

Hygiene standards and visitor regulations

Rules on hygiene and visitor behaviour are based on three foundational ideas: decreasing human presence, decreasing pathogen introduction and limit the risk of contamination (Leendertz and Boesch, 2013). Different rules and regulations exist for tourists, researchers and conservation staff at major African chimpanzee field sites. These can include: the wearing of facemasks, proper disposal of waste, prohibition against symptomatic individuals entering the forest, a limit to the number of visiting groups per day, time-limited visits, minimum human-ape distance requirements, hygiene barriers, quarantine for foreign researchers, and vaccination requirements (Kaur et al., 2008; Lukasik-Braum and Spelman, 2008; Williams et al., 2008; Leendertz and Boesch, 2013). Unfortunately, the rules are often broken when revenue and comfort takes precedence over safety (e.g. Woodford et al., 2002; Lukasik-Braum and Spelman, 2008; Macfie and Williamson, 2010).

The first visitation rules for mountain gorillas were implemented as early as 1985 and revised in 1999 (Lukasik-Braum and Spelman, 2008). Rwandan, Congolese and Ugandan

governments all regulate tourist numbers and human-gorilla distances. In the Congo visitors must wear masks whilst in gorilla habitat (Palacios et al., 2011).

Information is very scarce about which preventive measures are implemented against disease transmission from humans to orang-utans and bonobos. Some local guidelines exist for wild orang-utan tourism, where the basic aims are to minimize impact on vegetation and orang-utan social interactions, by for example never allowing tourists to exit vehicles such as boats or cars while viewing orang-utans (Macfie and Williamson, 2010). In comparing health evaluations of free-ranging and semi-captive orang-utans Kilbourn et al. (2003) discuss the importance of eliminating nonessential interspecies contact, overcrowding, dietary imbalances and stress in sanctuary populations, to prevent disease transmission.

Intervention

According to The Mountain Gorilla Veterinary Project 2002 Employee Health Group (2004), the use of vaccines in the great ape populations is not practical and, according to some, not ethical. Hence, efforts targeting park staff and researchers should be considered a veterinary precautionary strategy. On the contrary, Ryan and Walsh (2011) state that a completely hands-off approach is no longer enough to balance the risk of fatal disease outbreaks in great ape populations. They instead argue for using vaccines and possibly curative treatment. The authors do however stress that all interventions must continuously be evaluated for safety, cost-efficiency and effectiveness. Hands-on veterinary intervention is a very controversial matter, since interventions risk interfering with evolutionary processes where pathogens would be a part of natural selection (Deem et al., 2001; Robbins et al., 2011). However, few species are unaffected by human intervention in some form, since even observational studies to impose a small change in ecology. In Taï National Park, the rule of thumb is that treatment against life threatening disease is performed, if the disease can be suspected to be of human origin (Leendertz et al., 2006).

The Mountain Gorilla Veterinary Project, MGVP, was initiated in the 80's with the goal of using a "One Health" approach to health and disease surveillance, aiming to improve the sustainability in mountain gorilla populations (Cranfield, 2008). This coalition was the first to use veterinary treatment and care for individual animals in the wild as part of disease control strategies. Initially, efforts were directed solely at the gorillas – through post-mortem examinations and interventions. Since 2000, human and domestic animal interventions are also included in the groups' work, through initiatives such as the employee health programs described above. The mountain gorillas of the Virungas have increased in numbers since the 80's, directly due to human presence and interventions (Robbins et al., 2011). When comparing the survival of habituated and unhabituated groups, Robbins et al. (2011) found that conventional, non-interventionist approaches used in unhabituated groups, has led to a slight annual decline in population growth of -0.7% per year. This as compared to the habituated groups where the authors instead saw an annual growth of $+4.1\%$. Both rates were compared to a modelled baseline of $+3.1\%$, which only considers average reproduction and survival rates. The difference between the groups could be attributed to human presence, where 40% was calculated to be a result of direct veterinary interventions, and 60% due to the

increased monitoring and protecting against poaching. In the modelling, the authors also looked specifically at interventions during respiratory outbreaks. When calculating the change in growth rate if no veterinary treatment had taken place during respiratory outbreaks, the habituated groups' growth would have dropped to +3.4%. The authors concluded that efforts that increase survival in a population, such as veterinary interventions, are more efficient than efforts aiming at increasing reproduction, when trying to increase growth. In accordance with the conclusions of Ryan and Walsh (2011), Robbins et al. (2011) stress that while conventional conservation approaches might be both cheaper and more in line with what is considered "natural", they might not be enough anymore.

DISCUSSION

Ten years ago, Walsh et al. (2003) called for urgent measures to save the African great apes. Due to the rapid declines of the great ape populations in western equatorial Africa, the authors argued that all chimpanzee and gorilla species should be reclassified as *critically endangered* on the IUCN Red List. Still today, the conservation of great apes faces huge ordeals, without simple solutions. The threat of infectious disease outbreaks is only one alongside others, such as habitat loss, poaching and trade with live and dead animals. However, great ape disease is receiving more and more attention, as it is being realized that this threat is not one to overlook. Many outbreaks are feared to originate from humans, most probably researchers and conservation staff. At the same time, the presence of researchers and tourists has been shown to decrease poaching (Cranfield, 2008; Koendgen et al., 2008; Robbins et al., 2011). The question remains: is human presence in great ape habitat causing more harm than good?

The knowledge gap

There is a lack of reports, not only about the human-great ape disease transmission, but also about enzootic diseases, normal physiological parameters, which pathogens are in fact zoonotic in natural settings, and risks for and consequences of disease transmission from humans (e.g. Kilbourn et al., 2003; Lonsdorf et al., 2006; Koendgen et al., 2010; Ryan and Walsh, 2011). Many authors have called for precautionary, offensive strategies to prevent disease transmission to great apes, together with systematic screening, impact analysis and baseline data on great ape health (e.g. Whittier et al., 2001; Leendertz et al., 2006; Lonsdorf et al., 2006; Cranfield, 2008; Gillespie et al., 2008; Ryan and Walsh, 2011). The need for research in wild great ape health cannot be understated, since historical evidence of disease is mostly anecdotal or strictly observational. If health and disease would be studied in a more systematic manner, knowledge would be gained that allows for acting proactively in being able to recognize outbreaks earlier on, or hopefully preventing them altogether (Leendertz, 2008). Ryan and Walsh (2011) specifically stress the need for impact analysis of zoonotic pathogen transmission, since no study as of yet has addressed the true risk of disease spillover from humans in a scientific manner. For example: the use of facemasks or the restrictive minimum visitor distances have never been properly evaluated. The lack of impact analysis is also being addressed as a concern in the IUCN Best Practice Guidelines for Great Ape Tourism (Macfie and Williamson, 2010).

Today, we do not know for certain which human respiratory infections are high-risk for infecting great apes, although viruses have been shown to cross species barriers to a greater extent than bacteria (Pedersen and Davies, 2009). Our knowledge on disease transmission mostly originates from studies in captive environments (e.g. Szentiks et al., 2009; Kooriyama et al., 2013) and a few systemic studies of outbreaks in the wild (Koendgen et al., 2008; Koendgen et al., 2010; Palacios et al., 2011; Kaur et al., 2008). The studies conducted shed light on a reality where many human respiratory pathogens can be transmitted to at least chimpanzees and gorillas. There is little knowledge about the effect a natural environment has on both host and pathogen (Whittier et al., 2001). However, it has been shown that the pandemic human viruses HMPV and HRSV have penetrated the species barrier to wild great ape populations (Koendgen et al., 2008, Palacios et al., 2011), which is a reason for great concern and caution.

The impact of tourism

Tourism is not only an important source of income, but has been shown to lessen poaching in African national parks (Cranfield, 2008; Koendgen et al., 2008; Robbins, et al., 2011). Even though tourists might spend less time in great ape groups than researchers (The Mountain Gorilla Veterinary Project 2002 Employee Health Group, 2004), tourists are an important group to target in the prevention of disease transmission. The lack of understanding of the disease transmission risk is evident in the works by Muehlenbein et al. (2010) and The Mountain Gorilla Veterinary Project 2002 Employee Group (2004). Both reports show that despite showing disease symptoms and knowing about existing rules and regulations, both staff and tourists enter forests to go into near proximity of endangered great apes.

The importance of the existing regulations must be stressed to tourists, already during the booking process, with a clause stating that persons showing respiratory symptoms will be prohibited to go on the trek. When prohibiting sick tourists from entering the forest, all staff and stakeholders need to be informed that it is not the maximum number of visitors that gives success in the long-term (Ryan and Walsh, 2011). Prohibition of sick visitors might represent a short-term financial set back, but will in the long run help sustain the populations so that tourism can continue. Trekking for great apes is a once-in-a-lifetime experience, and those who do it likely have a genuine interest in the conservation of these animals. According to Lukasik-Braum and Spelman (2008), it should not be assumed that the tourists view visitation regulations as negative – maybe even the contrary.

The 2002 Orang-utan Conservation and Reintroduction Workshop emphasized that tourism should not be allowed in rehabilitation centres, and it also advised against further tourism initiatives in wild orang-utan habitat (Macfie and Williamson, 2010). Orang-utan sanctuaries and rehabilitation centres in Indonesia and Malaysia are popular tourist attractions, where close contact between humans and orang-utans presents a risk for transmission of disease. These animals are sometimes completely habituated, which according to the IUCN guidelines makes these centres dubious conservation tools. The shown differences in the prevalence of antibodies against different pathogens in captive and semi-captive populations of orang-utans is a problem that Kilbourn et al. (2003), concluded must be borne in mind when translocating

or re-introducing animals into the wild from shelters and rehabilitation centres, since this could potentially introduce pathogens to naïve wild animals.

Interventions

In the event of disease outbreaks, and specifically if transmission of disease from humans does occur, should we intervene and medically treat wild animals in a progressive, hands-on manner, or should we refrain from direct veterinary treatments in wild populations all together? To a great extent, this is an ethical question. Where should time, efforts and money be invested? How can a large-scale health or vaccination program be justified in a gorilla or chimpanzee population, when no health programs exist in the human populations that surround the national parks? Unfortunately the ethical considerations extend beyond the scope of this paper. However, no scientific report or study can answer the question if it is right to intervene. What we do know, is that the great apes have been pushed towards extinction by human activities. When humans now try to conserve the remaining populations, should we not try and do everything we can? Hopefully, great ape habitats will one day be respected and protected. By then, we need to have done everything we can in order to ensure that there are still viable populations left. Robbins et al. (2011) showed that human presence and veterinary interventions has had a substantial effect on population growth rates in mountain gorillas. Since this and other studies indicate that human presence does in fact lead to increasing growth rates (Cranfield, 2008; Koendgen et al., 2008), the risks of disease transmission that come with human presence might be outweighed.

Veterinary interventions in wild populations are often seen as not being “natural”. However, few species are unaffected by human intervention in some form, since even field observations do impose a small change in ecology. This is why Deem et al. (2001) argue that the discussion should not be about whether or not to intervene – but in what way. The authors state that it is no longer ethically defensible to cling on to a hands-off approach in conservation, especially not when battling disease. The use of available, safe vaccines against human pathogens that are suspected to be of danger to great apes should not be discarded on the grounds of it being too invasive. Neither should the use of curative treatment. Nevertheless, all actions or treatments – proactive or reactive – must be preceded by hazard analysis and risk assessment, and followed by evaluation. Assessments and evaluations should be done in a systematic manner, based on objective science, and shared with others in order to maximize benefit.

The Great Ape Health Monitoring Unit (GAHMU) is an international network that collects baseline data on general physiology and disease of great apes, through systematic sampling and surveillance (Leendertz and Boesch, 2013). One aim is to perform systematic risk- and impact analyses concerning disease transmission (Leendertz et al., 2006; Leendertz, 2008). The network hopes to make more validated diagnostic tests available for rapid pathogen detection in the field, which would lead to an increased readiness to act in the event of an outbreak in great ape, and potentially also human, populations.

Final remarks

Finding consensus and uniformity in the way health surveillance of the great apes is conveyed is valuable for validity and comparison of data. All examinations conducted – such as sample collection and post-mortem necropsies – should always be done according to established protocol, which should be continuously revised. The initiatives of GAHMU, and projects such as MGVP are necessary and promising for the future of great ape conservation.

There is an urgent need for a stronger connection between the research on zoonotic disease risk, and all persons that come into contact with great apes. Every person must wholly realize that his or her own behavior can potentially put the great apes at risk for contracting human diseases, and only researchers knowing about the risks will not increase compliance to rules and restrictions. To achieve increased compliance, risk communication and education needs to improve. Through popular science, current knowledge can be conveyed to the public, including the tourists that visit great ape habitat every year.

Finally, great ape conservation medicine in its true form cannot – and should not – be isolated from research in ecology, ethology, human medicine and social sciences. Neither can the health and disease of wild great apes be separated from the health and disease of human populations inhabiting the same area. Interdisciplinary approaches are needed – where combined efforts, combined knowledge, and work on several fronts form systematic, uniform strategies to minimize the risk of human-to-great ape disease transmission.

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Appendix 1. Summary of respiratory outbreaks at selected African chimpanzee field sites

	Outbreak	Group morbidity; mortality	Pathogen	Examinations	References
Mahale Mountain National Park, Tanzania	1993	NA; 11%	NA	NA	(Kaur et al., 2008, Hanamura et al., 2008, Ryan and Walsh, 2011)
	1994	NA; 15%	NA	NA	
	2003	98%; 7%	NA	NA	
	2005	52%; 3%	Paramyxovirus suspected	Necropsy, faecal samples, electron microscopy (EM)	
	2006	35%; 5% or 48%; 19%*	hrcMPV	Necropsy, faecal samples (viral PCR-assay), EM	
Gombe National Park, Tanzania	1968	63%; 8%	NA	NA	(Wallis and Lee, 1999, Lonsdorf et al., 2006, Williams et al., 2008)
	1975	NA; 1 individual	NA	NA	
	1978	NA; 1 individual	NA	NA	
	1987	40%; 17%	NA	NA	
	1996	NA; 11 individuals	NA	NA	
	2000	75%; 4%	<i>S. pneumoniae</i> ; <i>S. pyogenes</i>	Samples	
	2002	NA; NA	NA	NA	
Taï National Park, Côte d'Ivoire	1999	100%; 19%	HRSV; <i>S. pneumoniae</i> strain 2308	Necropsy, histology, PCR-methods, faecal samples	(Koendgen et al., 2008, Koendgen et al., 2010)
	2004	100%; 18%	HMVP; <i>S. pneumoniae</i> strain 2309; <i>P. multocida</i>		
	2006a	92%; 3%	HRSV; <i>S. pneumoniae</i> strain 2309		
	2006b	NA; NA	HRSV; <i>S. pneumoniae</i> strain 2308		

* - Confirmed and suspected morbidity and mortality respectively, due to missing individuals