Africa Journal of Animal and Biomedical Sciences 7(1), 2012
ISSN: 1819-4214

Risk assessment of human behaviours that may impact on the health of the Mountain Gorillas around Bwindi Impenetrable National Park, Western Uganda

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Abstract
Human behaviors have been found to play a role in transmission of disease causing agents between humans, their domestic animals and wild animals especially where the levels of human-animal interactions are very high as in the case of Mountain gorillas. There is increased traffic of pedestrians in Bwindi's southern sector and shared use of fallow gardens by gorillas, domestic animals and humans due to wild animal habituation and highly promoted eco-tourism, creating increased chances of exchanging disease agents. Using self administered questionnaires and interviews a cross-sectional study was carried out to assess the human-risk-behaviours that could be contributing to environmental loading with materials that are potential vehicles of pathogens in the southern sector of Bwindi Impenetrable National Park (BINP). The study population involved park staff, tourists, local communities living/farming close to the park boundary or using foot paths through the park. The human behavioral practices/actions that risk health of gorillas included direct encounter with gorillas while walking through the forest, defeacating, urinating and waste disposal, aerosol contamination by sneezing and coughing, uncontrolled resource use that may impact on the health of the gorillas. The local communities present the highest risk of about 83% compared to tourists and staff.. The registered human behaviours were source of environmental contamination and potential routes for pathogen transmission to the endangered mountain gorillas. Hence, public health education and sensitization, intensification in law enforcement and active epidemiological surveillance should be done so as ensure long term survival and conservation of mountain gorillas.

Keywords: Local communities, park staff, tourists, trails, tourism zone, environmental loading

Introduction

Bwindi Impenetrable National Park (BINP) located in south-western Uganda is home to the most critically endangered mountain gorilla; a flagship species whose conservation effort has benefited other resident animal species including 120 species of mammals, 348 species of birds, 220 species of butterflies, 27 species of frogs, chameleons, geckos and endemic species (1, 2, 3). The mountain gorilla population is assessed every five years to document the species' demography. A survey of the Bwindi gorilla population carried out in 2002 showed that it had increased since the previous census of 1997 by approximately 7% to 320 individuals (4, 5) and a recent improvement in the census methodology put the estimate at 340 gorillas (6). Loss of habitat to agriculture which had been the major cause of gorilla population decline (7) has increasingly been abated and disease risk was highlighted by the conservation community as a serious threat (8, 9, 10, 11, 12) in view of the fact that human-gorilla interaction was increasing within and around the already reduced and fragmented habitat.

The boundaries of BINP had resulted from 4 gazetting procedures which started in 1932 and culminated in attainment of the National Park status in 1991; upon which the road in the southern-tourism zone was closed and replaced with non-motorizable trail to facilitate transit of local people across the habitat. Proactive conservation for moutain gorillas involve patrolling within and outside the park by rangers and paramilitary teams, habituation of gorilla

groups for ecotourism and research and management of buffer zones.

Development of controlled eco-tourism based on gorillas brought in a new type of human dimensions in the management of this habitat. Specifically it involved habituating gorillas; a process in which the animal's fight and flight distances are compromisingly adjusted with eventual acceptance of man within their environment to within 5 to 7 metres (13), and establishment of a network of maintained trails frequented by humans in their effort to access gorillas in remote places of the habitat. Gorilla tourism is the single most important asset over which Uganda has an absolute comparative advantage when compared to Kenya and Tanzania and plays a catalyst role in that it is the primary attractant of over 80% of tourists who secondarily visit other wildlife protected areas in Uganda (14).

Gorilla viewing in BINP started in April of 1991 with only 2 habituated groups that were visited by 6 tourists each per day. Upon becoming a national park, the visitor daily quota was increased to 8 tourists per gorilla group and more gorilla groups were habituated. Between 1991 and 1997, about 3,600 tourists visited Bwindi each year, and the Park earned approximately US$1 million per year (15, 16). By 2007 there were four tourism gorilla groups all of which had their home ranges within the tourism zone (southern sector) with 11,680 available gorilla permits per annum of which 10,619 were sold representing occupancy rate of 92% (17). The necessity to re-distribute the incomes accruing from gorilla tourism multiplier effect led to habituation of five more groups all around the park. By July 2011 the number of groups habituated for tourism had more than doubled to nine; raising the available annual permits to 26,280. Given that for every gorilla group there was a 3-man advance team, 2 tourist guides/trackers, 2 SWIFT officers for tourist protection, and at minimum 4 tourist porters. Approximately 20 persons per group per day visit the gorrillas therefore bringing the total number of people that use gorilla trails to 65,700 per annum. If the current 92% occupancy rate is something to go by, this results in at least 60,444 persons.

The neighboring communities practice rotational agriculture at the periphery of BINP, where by a large area of farmland is allowed to fallow for one season to hold the soils on the steep hills while using it for livestock grazing before it is cleared for crops in another season. This attracts wildlife to the lush vegetation and at times they feed on overgrown crops which might be a factor in encouraging crop raiding. Habitat overlap between humans, gorillas and domestic animals do occur (18, 19) and has been found to enhance the dynamics of the gastrointestinal parasite and bacterial transmissions (20, 21). Sanitary behaviors of local people tending gardens or deterring crop raiding wildlife at the edge of the park may contribute to transmission of parasitic diseases documented in gorillas that use such localities (22, 23). Zoonotic disease transmission was particularly important in local communities around protected areas, which, in developing countries, tend to be surrounded by some of the poorest of the population with corresponding low primary health care and poor sanitation (24). Gastrointestinal pathogens of presumed human origin are known to occur in gorilla and chimpanzee populations that are subjects of tourism and research (25, 26, 27).

Humans and gorillas share approximately 97% of their genetic makeup (28), and owing to their close genetic relatedness, mountain gorillas were at an increasing risk of contracting human pathogens to which their immunity was naïve (29), with the potential of affecting their population (30). Intensification of human activities coupled with insensitive sanitary behaviours within and around BINP may be responsible for anthropozoonotic transmissions of infectious agents (31, 32, 33, 34, 35). World over, pathogens transmitted to apes in such contexts are now appreciated as drivers of ape population declines (36).

The mountain gorilla conservation community and the Uganda Wildlife Authority (UWA) have emphasized through the Bwindi Management Plan the urgency of monitoring both behavioral and physiological and environmental impacts exerted by various programmes executed in the gorilla habitat (37). This research was therefore carried out to assess potentially risky human behaviors which may contribute to environmental loading with parasitic and infectious agents when they are using trails in the

southern sector of Bwindi Impenetrable Forest National Park.

Materials and Methods

The study was carried out in December of 2011 in the southern sector of Bwindi Impenetrable National Park (BINP) and in villages of Buhoma, Mukono and Nkwenda which surround the park in Mukono parish. The study population included 1) local people using the Kisoro-Kanungu trail which traverses the tourism zone in the southern sector, 2) local communities cultivating and or living at the periphery of the park, 3) tourists returning from gorilla trekking or nature walks waiting for their certificates, 4) field and administrative park staffs who frequent the park by nature of their work. Data was collected by administering questionnaires tailored for each study group after explaining the reason for the study. The English versions of self administered questionnaires were given to tourists and staff and collected after they were filled on the same day. For the local people the questionnaires were verbally translated in Rukiga local language and administered as interview by the researchers and answers recorded on the English questionnaire to ease uniformity of the answers and data entry.

Purposive sampling was followed bearing in mind that the nature of the eco-tourism business and moving in and out of the forest deals with people who are in themselves samples of various populations. This was combined with random sampling in which every other tourist was given the questionnaire, and stratified sampling among the staff (administrative, guides, trackers, porters and patrol men). Data was generated from 40 local travelers at the Buhoma entry/exit point on the Kisoro-Kanungu trail, 36 local people who were found either in their gardens during the morning hours or were found in homesteads next to the park in the afternoon to evening hours, 36 park staffs on duty at their convenience after executing their assignments, 51 tourists when they were waiting for certificates at the park office after their forest activities.

Results

Bwindi Impenetrable National Park (BINP) employed 110 park staff at the time of the study and data was generated from 33% who were on duty during the study period. This category comprised of patrol men, administrators, trackers and porters: 47.2%, 22.2%, 16.7% and 13.9% (n=36) respectively. The average age of the park staff was 32.7 ±7.57 years. Over all 68.6% of the park staff indicated that they ease themselves in shallow dug cat holes while in the field in the park, while 31.4% eased themselves in the bush. There was varying levels of agreement on the established regulation on faecal disposal (whether defecations are buried) among respondents with 36.1% and 41.7%, of the staff agreeing strongly and fairly respectively while 22.2% disagreed. In addition, 86.1% of the park staff drank untreated water from streams while on duty.

The common methods of solid waste disposal documented during the study was by use of the provided trash cans (69.4%) and return the waste back to camp area (69.4%) as per instructions given to tourists.

During the study period, 40 local people were transiting through the forest composed of 72.5% males and 27.5% females, with average age of 33.9±12.1 years. Most of them (70%) were from Kanungu district particularly from Buhoma (35%), Nkwenda (30%) and Mukono (15%) villages which share boundary with the park and used the trail through the forest to cross to Kisoro District. The other villages were Ntungamo, Kanyashande and Keshero which were far from the park. Only 30% were from Kisoro moving in the direction of Kanungu.

When the local people were passing through the forest, most of them (92.5%, n=40) indicated that they are always fearful. Of those who were fearful, when asked what they carried for security, 44.4% (n=37) of them didn't carry any weapon for protection, 31% carried sticks which double as walking sticks and for defense if needed. They all conceded that the confidence in feeling secure lay in moving in groups and no single individual was seen crossing the forest alone. About 82.5% admitted to have met gorillas on their way through the forest. They were sensitized on what to do when they met gorillas as none of them fled, attempted to hide or were chased by the gorillas.

Regarding other disease transmission routes 80% of the respondents drank water from streams when they were passing through the park without treatment. About 62.5% ate their food while inside the park, but only few of them (44%

n=25) carried the trash or food remains for disposal outside the park and the rest threw such materials inside the park. About 97.5% (n=25) used hankies when blowing their nose, 40%(n=25) used bare hands and smeared the mucus on the vegetation and 22%(n=25) harvested and used vegetation leaves which are then thrown along the trail.

The mean age of the local people interviewed in Mukono Parish was 40.4 years, which were 72.2 % and 27.8% males and females respectively. Up to 94.4% of respondents reported that gorillas go to their villages at the rate of 3.4±2.5 times a month. Regarding the activities carried out along the park boundary, 77.2% indicated that they cultivated up to the forest boundary while 22.8% did not. Forty one point seven percent tethered domestic animals along the park. When carrying out their activities they either defecated in their gardens (78.1%; n=34) or used forest park bushes 50% (n=34) close to their gardens. For those who brought their children with them, 22.9% (n=35) reported that their children also defecate in bushes. Normally children under the age of 15 years are not allowed to access the great ape parks because of disease transmission risks. The majority (72.7%; n=33) worked all day and ate their lunch from gardens, and 95.8% (n=24) of them threw the food remains in the gardens and bushes while only 4.2% carried food remains back to their homes.

At the time of the study, BINP received 56 visitors who tracked gorillas on daily basis and 43% of those visitors accessed gorillas in the southern sector. In addition there were other visitors who came for other activities like birding and nature walk. The mean age was 45.8±15.6 years. On average they indicated that they had been away from their home country for an average of 13.8 days. Most of the tourists (98.0%) indicated that it was their first time to come to BINP. They were dominated by visitors from Europe (41.2%), followed by those from the Americas (30%), Australia (20%), Africa (10%) and Asia (8.8%).

All the respondents (100% n=51) had tracked gorillas at the time of filling the questionnaire. In addition 27.5% and 9.8% had already participated in nature walk and birding respectively though some tourists could carry out these activities concurrently depending on an individual's plan in the park. Of those who tracked gorillas 13.3% (n=45) had ate or drunk their packed lunch while in the forest and 86.7% did not as they were not hungry since tracking had taken them only few hours in the morning. When asked about the disposal of food wrappings and remains, 71.4% (n=7) indicated that they carried them back in their bags. About 68% of the total tourists sample engaged in sanitary behaviors while inside the forest which were dominated by urination (39.2%; n=35) followed by sneezing using tissue (25.5%) and lastly defecation (21.6%) in catholes in which the used tissues were buried. These actions were not mutually exclusive

During visitor briefing before entering the forest tourists were instructed to seek guidance from the guide/tracker for any activity that they wanted to do for example when they want to ease themselves. Sixty one point one percent (n=36) didn't seek guidance while 38.9% first sought guidance from the guides. This shows that there was a possibility of the visitors breaking the regulations on sanitation measures/guidelines put in place to deter disease transmission from humans to wildlife. About 25.6% (n=43) indicated that they saw various actions such as urination and spitting done by various tracking personnel. On considering all activities participated in by tourists, including gorilla tracking, birding and nature walk, 76.5%(n=51) indicated that they ate their lunch while in the forest and when asked what they did to avoid contamination of their lunch with dirt in their hands which could have been picked from the vegetation and ground, most of them (73.3%, n=30) showed that they didn't do anything and 26.7% wiped their hands with tissue before eating. Furthermore, 70.5% (n=44) agreed with the statement that there was need to have water to wash hands before eating while in the forest. Seventy five percent (n=44) indicated that they were so hungry and exhausted that they didn't care about cleanliness and possible source of contamination to the food they ate. When asked whether the guides/trackers cautioned tourists on how to handle the food they ate while in the forest, 70.1% (n=43) indicated that they had been pre-cautioned and 29.9% were not told what to do.

Discussion

The results have shown that most of the park staff visited the gorilla habitat regularly with the patrol men taking the highest percentage of 47.2% since they participate in tracking, nature walking, birding and security activities every day. The park staff were sensitized about the gorilla rules and regulations, most of them buried their faecal materials, usually 30 cm hole as recommended but 31.4% clearly showed that they use the bush when they want to ease themselves. This combined with the fact that up to 22.2% confirmed that faeces deposited in the forest were not often buried, revealed a potential disease risk that could have devastating consequences on endangered species (9, 38) from the people who were supposed to enforce regulations which they themselves had read to visitors. There seemed to be an assumption that the park staff obeyed their own regulations. However the current results indicated to the contrary. The proportion of the park staff who had this behavior had doubled compared to the situation nine years ago when only 16% confessed not burying faecal materials (34). This was a dangerous situation given that the same staff frequented the forest on daily basis compared to tourists. A possible explanation could be derived from the field observation that during tracking whenever a tourist goes to ease themselves, the whole group would wait for the person. But on the other hand, if it was done by the park staff, it was done at their own convenience while the rest of the group moves on. Therefore they would have to rush through the process in order to catch up with the rest of the group which has moved on. This causes one to wonder whether someone in such a hurry has sufficient time to dig a hole of at least 30cm (1 foot) deep, and cover it up after easing. There had not been frequent disease out breaks among gorillas in Bwindi compared to the Virunga population where disease cases were frequent. Field park staff and top management should therefore ensure more vigilance in enforcing compliance among staff as the cost of a single disease outbreak has the potential to decimate such small population of endangered great apes which resided in the park.

Because the park staff interact with local people on daily basis, coupled with the fact that they were only vaccinated for against childhood diseases (39). It should be seen that they had a high chance of "trafficking pathogens" contracted from the local population to the gorillas (28) with which they interact on daily basis, making such steadily increasing laxity in disposal of faeces in the park by staff unacceptable. In December 2007 marked the onset of infectious respiratory disease outbreak that took place in Bwindi gorillas since their habituation in 1993. The cases in Habinyanja group which were severely affected and recovered after treatment with Enroflaxin at 10mg/kg body weight, though the cause and source of the infection was not established. The role of staff in such transmission could not be ruled out given that there was another arthropo-zoonotic infection of clinically significant sarcoptic mange has ever been reported in Bwindi Impenetrable National Park (22, 40). Therefore the documented laxity in sanitary behaviors among park staff justifies instituting an 'Employee Health Care" model in Uganda like it has been practiced by gorilla conservation agencies in Rwanda and DRC in partnership with Mountain Gorilla Veterinary Project (MGVP) (8). This should be combined with rigorous supervision and monitoring the park staff for compliance as regards all park regulations.

On the other hand it would be in the interest of the park staff to make sure that sanitary measures were adhered to since the majority of them consistently drink untreated water from streams in the forest when they are on duty. This behavior has increased in , and for the last 9 years from 79% (34) to the current level of 88.9%,. This implied that staff were increasingly not packing enough safe water for their personal use when they go out on tracking expeditions. Also Uganda Wildlife Authority (UWA) had been known to have a high rate of transferring staff among her 10 National Parks hence the new transferred park need to sensitized about the sanitary regulations.

It was noted that the local people mostly cross the forest on market days which was on Tuesday in Kisoro. There many movements of people during during the Christmas and New Year festivities. During this period the people moved to and fro visit relatives and friends. Despite the high rate of meeting gorillas foraging around the trail, there were no recent reported injuries resulting from gorilla-human encounters. It seemed that most people know how to behave to avoid having confrontation with gorillas and other wildlife. Unfortunately most of them

(83.3%) confessed using forest bushes to ease themselves when they were on their journey. This could be a source of pathogens to mountain gorillas. The solid faecal waste was not buried and they used natural leaves for cleaning themselves. There was a high potential risk for the gorillas coming in contact with human excrement along the trails. These rick could be be minimized by establishing public pit latrines at appropriate sites along the trails. Alternatively the people should be sensitized and allowed to carry a machete or trowel per group so that a cathole could be dug whenever one goes to ease themselves. Instructions to disperse urine deposition should be posted at the head of the trail. This would make sure that no single points were urinated at; which would attract animals to lick mineral and possibly increasingly get in touch with microbes of human origin.

The current study has shown that most local people who use the foot path take their lunch from the forest as it takes between four and six hours to cross from Kanungu to Kisoro areas and vice versa. They found that after eating, the food remains were disposed in the forest. The food remains and their wrappings contaminated the environment and could be a media for multiplication of some pathogens such as *Salmonella*, and toxin producing fungi.. In addition, the local people blowed their nostrils and cleaned using leaves or bare hands. Spitting also could contribute to loading the trail environment with respiratory microbes thus creating conditions for mountain gorilla to acquire infection through contact with such materials as they forage on the leaves or through air born transmissions from the dust especially during the dry seasons. Through this route, the anthropo-zoonotic microbes such as tuberculosis, RSV, HMPV and *S. pnuemonie* could find their way into the gorilla and other wild animal populations.

It was also found that the local people who used the foot path drank the running water in the forest, since they didn't carry any cup they had to first wash their hands and in so doing they contaminated the streams with microbes. This could serve as a source of water-borne infections to humans and gorilla population downstream.

The local people peripheral to the park boundary who carried out crop cultivation and tethered domestic animals near the park reported that they used their gardens and nearby park bushes for easing themselves. Children who were prone to childhood communicable diseases accompanied their parents to the gardens and used the same bushes. Although some people clamied that they took back food remains. But given the low state of the primary health care in these villages, it was doubtful whether anyone would bother carry food remains back home unless it was saved for a evening meal. These food remains left in such environment had a high probability to be picked by the gorillas and other park animals since they frequent these village gardens. It has been known that these described patterns of poor human hygiene facilitates human-livestock bacterial transmission (21. A wide variety of domestic and wild animals could act as reservoirs for pathogens including viruses, bacteria, or parasites (41), and such increasing proximity of human and gorrilla populations could create a conducive platform for exchange of zoonotic diseases that had so far been documented in BINP. This risk could be minimized through increased and constant sensitization of neighboring communities on the importance of practising proper sanitary behaviors as their contribution to continued existence of the mountain. Gorillas as it would benefit them through the revenue sharing scheme and the multiplier effect of the eco-tourism industry (42, 43).

Most tourists on gorilla tracking, nature walk and birding activities did not ease themselves in the forest but 26.9% did defecation in the forest, and a slightly higher percentage of them urinated in the forest. During tourist briefing at the park office, tourists were encouraged to use the toilet facilities in the park headquarters before setting for tracking so that low rates of defecation and urination could occur. However it may be urged that the tension and anxiety involved in the gorilla tracking exercise did reduce the gastro-intestinal motility, and when combined with the negative psychological impact of having to tell other people that one was going to ease themselves may contribute to some people deploying their central nervous system to suppress the desire to go to toilet till they were at place where they have proper facilities. Such phenomenon has been proved experimentally in which stress activated the Brain-Gut Axis (BGA) activities mediated by numerous chemical mediators and involvement of the vagal system, resulting into markedly reduced ingesta transit time in the upper gut, including the stomach and

small intestine while conversely the large bowel motility increases with increased stool output and transit speed (44, 45, 46).

Those that eased themselves in the forest buried the used tissue which was not the desired method of disposal in outdoor recreation. This meant that use of natural tissue in form of leaves would ensure that no foreign material is left in the forest. However, currently management in BINP and indeed in the whole of the gorilla range countries has no instruction on the better methods of disposing the used tissue. The option of carrying out used tissue as recommended in other parts of the world had not yet been suggested in the gorilla habitat and its acceptability had yet to be investigated. A good percentage (25.2%) of the tourists voluntarily sneezed using Kim tissue and packed it in the waste bags. However sneezes resulting from the reflex actions did occur. Hence there was a need to constantly remind tourists to make an effort to face away from gorillas when sneezing during gorilla observation. This is important because it had been found that some tourists were not up dating their vaccination requirements and were not declararing their health status when they are sick (39).

Travelers could bring new strains of pathogens to an area with showing obvious clinical signs (47). In the current study, most tourists had been travelling for over two weeks before reaching Bwindi and the stress resulting from travelling could lead the tourists to shade the disease organisms as they tour. This could be through aerosols or shading of the organisms via the faecal route. This could aid the quick spread of the diseases from one tourism area to another. The apes are known to be immunologically naïve to most of the diseases from other areas. Any infection may result in disease outbreaks with disastrous effects on the endangered gorilla population before the gorilla conservation community may be able to contain it.

On the other hand, tourists reported that the tracking exercise rendered them so exhausted that they did not care about the possibility of contaminating the food they ate when tracking. This left them prone to infecting themselves with disease agents they could have picked from the environment (vegetation, soil) during the tracking exercise, particularly from the trees along the trails. These trees were usually handled by various people repeatedly when seeking support or short rest during the hiking exercise since the terrain in most parts of Bwindi tend to be steep. Exposure to environmental microbes could contribute to diseases such as travel diarrhea that can be experienced in their next destination (48, 49). Alternatively this practice could also contribute to "microbial traffic"; that is, the introduction of existing pathogens from BINP into human populations elsewhere. Through movement of tourists these pathogens picked from BINP tourists trails could further be disseminatied larger populations with a possibility of hence becoming emerging or re-emerging diseases (50, 51, 52).

Faeces and urine from both humans and other animals were likely to be the largest source of environmental loading of pathogens associated with water-borne transmission. Studies need to be done on loading, prevalence, concentrations, survival and infectivity for the various pathogens associated with urine and faeces. It was known fact that that more than half of the bacteria in the human intestines and more than 99% of the environmental bacteria had not been cultured or characterized (53, 54, 55). Since the forest was very vast, most times it took the whole day to track the gorilla families if they were deep in the forest.

Many factors affected the ability of an infectious agent to be transmitted through the environment (56, 57, 58). First, the infectious agent must enter the environment. For most water-related pathogens, the organism enters the environment via human or animal faeces deposited on land or in water. Some organisms enter the environment via human and animal urine such as *Leptospira* and schistosomes. Sputum deposited in the environment was a convenience vehicle for respiratory system pathogenic organisms such as *Streptococcus occidian*, *Haemophilus occidian*, *Staphylococcus aureus*, *Legionella pneumophila*, *Mycoplasma pneumonia*, *Klebsiella occidian*, *Pseudomonas aeruginosa*, *Bordetella pertussis* and other *Mycobacterium* species. The load of organisms entering the environment depended on the prevalence of the infections in the population of humans and animals, the concentration of the infectious agent in the faeces, urine and sputum and how long an infected individual will shed the organism. This study identified the sanitary behaviors which facilitated loading the Bwindi environment with a number of pathogenic organisms. Efforts should therefore be made to establish an active

epidemiologic surveillance in order to provide an early warning clue of the likelihood of disease outbreak.

Therefore the increased number people who use the foot path and forest trails along the park forest equally risk contracting water borne infections as a result of drinking unboiled or untreated water from the streams flowing through the park. Microbial contamination indicators in stream water should be monitored in BINP to continuously to document the sources and direction of movements of pathogens being loaded in the habitat.

The ability of the organism to persist in the environment is usually critical to its transmibility. The longer an organism can persist, the more likely it is to have the opportunity to come into contact with a susceptible host. Survival time in water depends on many physical factors like pH, temperature, sunlight as well as characteristics of the organism. The survival of water-related pathogens in water ranges from hours to years. Some pathogens, such as *Salmonella, Campylobacter* and *Vibrio occidi*, are capable of entering a dormant state described as "viable but non-culturable" form which allows them to survive longer under adverse conditions in the aquatic environment and yet maintain their pathogenicity (59). Other pathogens have a stage in their life cycle such as a spore or oocyst that is environmentally resistant for example *Clostridia*, *Bacilli* and occidian. These spores or oocysts can survive for very many years in the environment even in harsh conditions. The ability of the organism to replicate in the environment is also important. Under favourable conditions, some water-related pathogens can multiply in the aquatic environment and reach high concentrations. However this is not possible for viruses and protozoa that are obligate parasites. The climate for BINP was tropical with two rainfall peaks from March to May and September to November, with an annual precipitation which ranges from 1,130 to 2,390 mm and annual mean temperature ranges from a minimum of 7-15ºC to a maximum of 20- 28ºC (60, 61). Such environment provided an adequate moisture and water that could potentially ensure the survival of many of organisms loaded in the habitat and in addition the heavy rain run-off provided a vehicle for spreading the microbes from the point of deposition to another.

Human behaviours documented in this study presented potential risks of transmission of diseases to already critically endangered population of gorillas and among human population. Hence, the existing BINP visitor regulations needed to be revised to incorporate vaccination requirements and more information packages. Community sensitization on public health concerns should be undertaken and where possible installing waste containers and toilets at critical points on the road and walk trails through the park.

Acknowledgments

We greatly acknowledge the Mountain Gorilla Veterinary Project (MGVP) Inc. for providing the logistics in executing this study. The Uganda Wildlife Authority (UWA), for the permission to carry out the study in Bwindi-Mgahinga Conservation Area (BMCA). The respondents for their cooperation and providing the valuable information.

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