Int. Zoo Yb. (2007) **41:** 110–121
DOI:10.1111/j.1748-1090.2007.00021.x

An integrated health approach to the conservation of Mountain gorillas *Gorilla beringei beringei*

M. CRANFIELD[1,2] & R. MINNIS[1,3]
[1]*MGVP Inc., The Maryland Zoo in Baltimore, Druid Hill Park, Baltimore, MD 21217, USA,* [2]*Department of Molecular and Pathobiology, Johns Hopkins University, Baltimore, MD 21205, USA,* [3]*Mississippi State University, Wildlife and Fisheries, Starkville, MS 39762, USA*
E-mails: mrcranfi@bcpl.net, rminnis@CFR.MsState.Edu

Conservation medicine, the medical practice that seeks to promote ecological health and well being of a defined habitat, functions at the intersection of animal, human and ecosystem health. It differs from classical public-health epidemiology and medicine in that it aims to protect and improve animal health and related ecosystems, in addition to human health. Zoonotic diseases and emerging diseases are of primary concern and are particularly important when Endangered great-ape populations are involved. The effective practice of conservation medicine demands an integrated cross-disciplinary team approach involving wildlife and livestock veterinarians, local physicians, public-health professionals, ecologists, government officials and communities. Common interests, improved data collection and economies of scale argue for combining health surveillance, data and delivery efforts. This team approach needs to be tailored to the infrastructure and sophistication of the host country's human and livestock/wildlife health systems. It is often, by default, the wildlife veterinarian(s) who coordinate(s) the integrated 'one health' approach because of their training in wildlife and livestock medicine as well as in zoonotic and emerging disease issues. This paper describes the Mountain Gorilla Veterinary Project's (MGVP Inc.) collaborative cross-disciplinary strategy for Mountain gorilla *Gorilla beringei beringei* conservation and the database system developed during the process.

Key-words: conservation medicine; IMPACT™; MGVP Inc.; mountain gorilla.

INTRODUCTION

The Mountain Gorilla Veterinary Project (MGVP Inc.), centred around the Mountain Gorilla Veterinary Center (formerly Volcano Veterinary Center), began at the request of the anthropologist the late Dr Dian Fossey. For 18 years, Dr Fossey studied the behaviour, social interaction and environment in Rwanda's Volcanoes National Park for the highly Endangered (IUCN, 2006) Mountain gorillas *Gorilla beringei beringei*. Her studies indicated that the number of Mountain gorillas was rapidly declining, partly owing to human-caused disease and injuries. By the mid-1980s, only 248 known Mountain gorillas remained in the world. Dr Fossey quickly changed the emphasis of her research from Mountain gorilla behaviour to protection.

In 1985, Dr Fossey and wildlife enthusiast Ruth Morris Keesling, daughter of Morris Animal Foundation founder Dr Mark Morris, met at a primate conference in San Diego, CA, USA. Dr Fossey requested funding for a veterinary programme to ensure the survival of the Mountain gorillas, and Ms Keesling responded with the idea of the MGVP. Sadly, Dr Fossey's death followed this request but the promise was kept. In 1986, the now late Dr James Foster founded the Mountain Gorilla Veterinary Center in Rwanda. Since then, many leading wildlife veterinarians have served there. In the early 1990s, a genetic study by Dr K. J. Garner and Dr O. A. Ryder confirmed that a second island-population of extremely closely related gorillas, the Bwindi Mountain gorilla *Gorilla beringei bwindii*, was living in Bwindi National Park, Uganda (Garner & Ryder, 1996). This discovery doubled the number of known Mountain gorillas to *c*. 650. From the most recent census (Pickrell, 2004) there has been an estimated 17% increase in the last 10 years in the Virunga Massif population alone to 380

individuals. A 2002 census in Bwindi National Park revealed 320 individuals. This now brings the total to an estimated 700 Mountain gorillas living in dense forests located in national parks in Rwanda, Democratic Republic of the Congo (DRC) and Uganda. There are no known Mountain gorillas in captivity.

The largest threat to gorilla species in general is logging, with subsequent loss and fragmentation of habitat, and increased access for the commercial bushmeat industry (Wallis *et al*., 2002). Mountain gorillas live in the protected areas of four national parks; as a result, logging and commercial bushmeat are not considered major threats. The potential exposure to and transmission of human and livestock diseases to gorilla populations is the third highest threat to gorilla species in general but the largest threat to Mountain gorillas in particular (Werikhe *et al*., 1998).

Conservation medicine, the medical practice that seeks to promote ecological health and well being of a defined habitat (Pokras *et al*., 2000), functions at the intersection of animal, human and ecosystem health. MGVP Inc., was considered by many to be the first project of its kind and continues to be one of a limited number of veterinary efforts to provide individual health care to animals in a natural habitat in an effort to enhance the long-term sustainability of a small and dwindling wild population. Initially, the veterinarians focused on (1) clinical interventions for life-threatening or human-induced situations and (2) performing post-mortem examinations. More recently, the need to be involved in a more integrated holistic 'one health' approach was recognized. This includes facilitating health care to the Mountain gorillas and other species that interact with them, such as the wildlife sharing the same habitat, and the dense human and domesticated-animal populations around the Virunga Massif and the Bwindi Impenetrable Forest. MGVP Inc., attempts to understand these interactions with respect to potential disease transmission and manage them through (1) capacity building, (2) research, (3) health care and (4) the IMPACT™ (Internet-supported Management Program to Assist Conservation Technologies) database system that links all the efforts.

MGVP INC.

The MGVP has undergone many structural changes over the years, the details of which are too lengthy for this paper. At the time of writing, MGVP Inc., is an American not-for-profit foundation, affiliated with The Maryland Zoo in Baltimore, MD, USA. MGVP Inc., has a Board of Directors to run the foundation and an Advisory Committee consisting of expert veterinary wildlife clinicians, pathologists and epidemiologists, as well as a spatial ecologist and a human epidemiologist. The project is managed from the United States of America by a Project Director with two part-time staff. MGVP Inc., functions in Uganda, the DRC and Rwanda as a Non-Governmental Organization (NGO) with a Memorandum of Understanding (MOU) with the governmental department in charge of conservation in each country. There are two expatriate veterinarians and one Rwandan veterinarian at the regional office in Ruhengeri, Rwanda, two Congolese veterinarians in Goma, DRC, and two Ugandan veterinarians working out of Makerere University, Kampala. MGVP Inc., is active in the three parks of the Virunga Massif and in the Bwindi Impenetrable Forest in Uganda that contain the entire population of the Mountain gorilla *G. beringei beringei*. MGVP Inc., has an MOU to provide financial and personnel support to the Wildlife and Animal Resource Management Department (WARM) of the Faculty of Veterinary Medicine of Makerere University in Kampala, Uganda. MGVP Inc., has also recently begun to be active in the upland sector of Kahuzi Biega National Park, DRC, that contains Eastern lowland gorillas *Gorilla beringei graueri*.

In 2000, the MGVP Advisory Committee and staff, along with other invited experts, produced a strategic plan for MGVP Inc. The plan included a general vision statement to be 'the premier research and health-monitoring resource for achieving self-sustaining

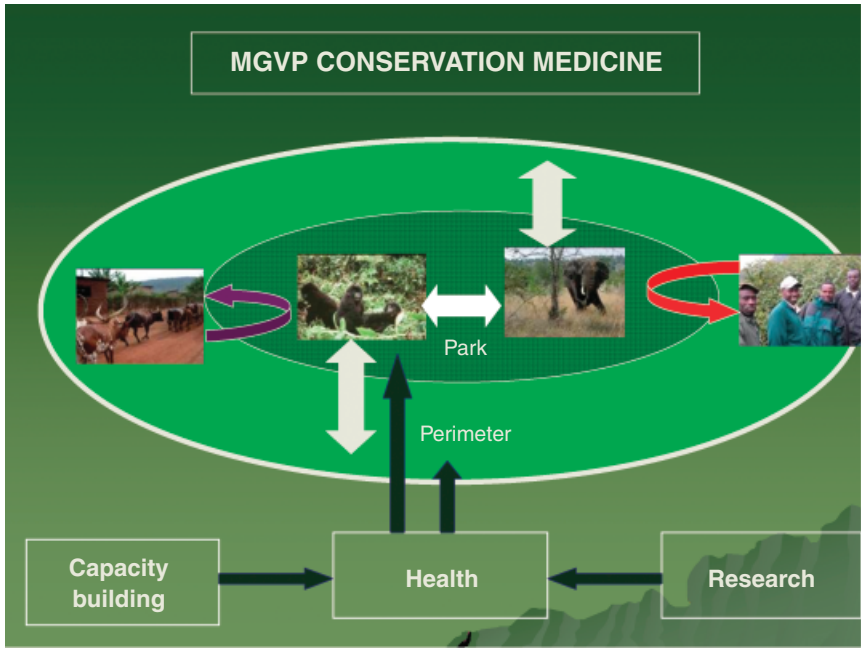


Fig. 1. The MGVP Inc., approach to Mountain gorilla *Gorilla beringei beringei* health incorporates the health of the humans and domesticated animals living in the same protected areas in which the gorillas live, as well as research and capacity building. MGVP, Mountain Gorilla Veterinary Project.

Mountain gorilla populations' and a more focused mission statement to 'improve the sustainability of the Mountain gorilla populations' by (1) monitoring the health of the population, (2) providing health care, (3) conducting relevant health studies and (4) disseminating information. Capacity building, research, and health monitoring and delivery are the three main activities implemented to accomplish this mission. MGVP Inc., attempts to develop programmes and technologies that have applications in a larger context to other species, not just gorillas. Figure 1 reflects the approach of MGVP Inc., which considers the health of the gorillas as dependent on a wide circle of health of the surrounding populations with which they interact. It takes an integrated team of many disciplines to accomplish this comprehensive concept of ecohealth. MGVP Inc., must integrate into the overall goals of the combined government agencies and NGOs that are interlinked with the broader ambitions of the community and country, as well as the local objectives for the park and gorillas within. Lastly, the team must be flexible in order to implement these strategies within different political and cultural situations.

Capacity building

Ultimately, if the MGVP Inc., programme is going to be considered successful, it must be sustainable, with methodologies that can be supported and utilized by the local community. Sustainability is largely dependent on capacity building, whether it is facilities, technology or personnel training. MGVP Inc.'s, capacity-building programme comprises:

- field training by expatriate veterinarians who rotate through the project every 1–4 years. They are highly specialized wildlife veterinarians from around the world who bring various areas of expertise to the project and teach the local

veterinarians through formal and informal lectures, and activities in the field;
- regional meetings of veterinarians and/or trackers and guides, hosted by MGVP Inc., to teach about health-monitoring or specialized techniques, such as geographical information systems. Participation often includes partner NGOs and government conservation agencies;
- library development, student field activities and a 'professor' at the WARM Department are all supported by MGVP Inc. With the help of MGVP Inc., and other sponsors, WARM has for some years been offering a post-graduate wildlife programme leading to an advanced degree. This has resulted in an increase of more qualified graduates taking positions of leadership and stewardship with regard to wildlife. MGVP Inc., is attempting to reproduce the WARM student capacity-building programme in Rwanda and DRC;
- African veterinarians are taken to the The Maryland Zoo in Baltimore for a 6 week training course that includes small-animal medicine, zoological cases, an immobilization course and post-mortem techniques.

Two positive outcomes of The Maryland Zoo in Baltimore course are, first, that the attendees are better equipped to take full advantage of the on-the-job training with the expatriate veterinarians once they return to Africa. Second, they are exposed to the cultural background of the expatriate veterinarians, creating a better understanding between the expatriate veterinarians and African veterinarians as to job performance and expectations.

Research

Since the development of the strategic plan, the project has put a stronger emphasis on research. This is reflected in the sponsorship/facilitation of two completed PhDs and three completed Master's degrees. There are one ongoing PhD and two ongoing Master's degree programmes at the time of writing. This research is in addition to that traditionally conducted by the field veterinarians as a part of their daily routine.

One of the more important research components within MGVP Inc., is the undergraduate programme at WARM that involves final-year veterinary students. Students must conduct and write research projects on aspects of gorilla conservation that will help the project fill data gaps. These projects are supervised at the planning, implementation and writing stages, and the supervisor encourages the students to submit their findings to peer-reviewed journals.

To further enhance research, MGVP Inc., has also developed an organized biological resource centre at The Maryland Zoo in Baltimore. At the time of writing, the project was facilitating the development of similar centres in each of the three partner countries to enable splitting of the biological material, thus ensuring the future safety of valuable samples. Samples are collected, processed and stored with set standard protocols. The protocols and sample inventory are posted on the IMPACT™ website (described later). This gives researchers around the world access to a wide variety of samples maintained under various storage conditions. The facilities provided by biological resource centre have enabled several studies to be completed by research groups unrelated to the project without the need to enter the parks to collect additional samples, thus resulting in minimal disturbance to the habitat. By using samples from the same or at least known individuals, processed and stored in the same fashion, and then applying the same methodology to them, comparable findings/results are ensured over time. At the time of writing, samples were collected from known individuals of humans and gorillas and, on a population basis, from other species that interact with the gorilla habitat. Regardless of the species, Global Positioning System locations and some history associated with the sample were recorded. The result is thousands of samples, mainly mammals (livestock, humans, several species of primates and other wildlife, such as rodents), available for research. The samples are distributed if a submitted study

application passes criteria that take into account the merit of the study (e.g. likely contribution to the management of the Mountain gorillas), the amount of sample available in the biological resource centre and the ability to replace the sample.

There have been 24 refereed papers, two book chapters and 22 abstracts produced by MGVP Inc., present or past employees in the last 7 years. An example of one of the more important series of research studies with a management implication is on *Microsporium*, *Cryptosporidium* and *Giardia* in gorillas, cattle and humans at the interface of the Bwindi Impenetrable Forest and the community (Nizeyi *et al*., 1999; Graczyk *et al*., 2001; Graczyk, Nizeyi, DaSilva *et al*., 2002; Graczyk, Nizeyi, Ssebide *et al*., 2002; Nizeyi, Cranfield & Graczyk, 2002; Nizeyi, Sebunya *et al*., 2002).

Polymerase chain reaction and sequencing of these organisms supported the occurrence of transmission of these organisms between the three species. It was concluded that faecal–oral routes of transmission existed and, although the organisms studied do not have serious impact on the affected populations, it showed the ease with which more serious diseases (e.g. polio) could be transmitted (Nizeyi *et al*., 1999; Graczyk *et al*., 2001; Graczyk, Nizeyi, DaSilva *et al*., 2002; Graczyk, Nizeyi, Ssebide *et al*., 2002; Nizeyi, Cranfield & Graczyk, 2002; Nizeyi, Sebunya *et al*., 2002).

Measles, tuberculosis and Ebola are considered major threats to the gorilla population. In 1989–1990, there was a suspected outbreak of measles and 60 gorillas were vaccinated in the home range of the affected animals. Although the cause for the respiratory disease outbreak was never definitively diagnosed, the outbreak subsided after the vaccination programme. This indicated that, if necessary, a sizeable portion of the Mountain gorilla population could be vaccinated in the face of a disease outbreak.

Serum samples ($n = 40$) collected opportunistically during recent (2001–2006) interventions were analysed for evidence of exposure to various infectious agents (Whittier *et al*., 2005). Mountain gorillas had antibodies against or antigens to 14 different viruses, including influenza A and B, parainfluenza types 1, 2 and 3, measles, human herpes simplex 1, simian agent 8/African monkey herpesvirus, Epstein–Barr virus, chimpanzee cytomegalovirus, adenovirus, hepatitis A and B and simian agent 11/rotavirus. Positive titres were also detected for *Mycoplasma pneumoniae*. All gorillas examined to date have been negative for respiratory syncytial virus, human varicella zoster, simian retrovirus, simian immunodeficiency virus, simian T-lymphotrophic virus, foamyvirus, encephalomyocarditis virus, lymphocytic choriomeningitis virus, filovirus, mumps, human immunodeficiency virus type 1, Q fever, eastern equine encephalitis, western equine encephalitis, St Louis encephalitis, California encephalitis, hepatitis C, simian haemorrhagic fever virus, reovirus and monkeypox. Anecdotal evidence suggests that severe respiratory disease outbreaks in Mountain gorillas may be caused at least partly by parainfluenza type 3, as the majority of gorillas seropositive for this virus were from groups that had recently experienced such outbreaks (Whittier *et al*., 2005). While the prevalence of measles titres is low (1/40) in the gorilla population, a review of local hospital records reveals that cases of measles still occur in the local human population despite a national childhood vaccination programme. This indicates that the possible transmission of measles from humans continues to be a real threat to a relatively naïve population of gorillas.

Health care

Gorillas The health care of the gorillas can be divided into (1) health monitoring, (2) interventions and (3) post-mortem examinations.

Individual health care for *c*. 50% of the Mountain gorillas is possible because of habituation. Dian Fossey habituated the Virunga Mountain gorillas to the presence of humans at close distances to enhance her behavioural studies. More recently, further gorilla groups have been habituated to

support a very successful tourism industry. Approximately 70% of the Virunga Massif gorillas, 30% of the Bwindi gorillas and a handful of Eastern lowland gorilla groups are habituated.

1. *Health monitoring* The day-to-day gorilla health monitoring carried out by trackers and guides, researchers and veterinarians is the basis of the health delivery system. This is a syndromic surveillance system that involves two levels of input. The first is a form filled out, either in English or in French, by trackers and guides who record abnormalities in seven parameters of body condition, activity, respiration, skin/hair, discharge from the head, other discharge and faecal output. The second form is more complicated and is used to record the clinical signs associated with the parameters and is usually filled out by the veterinarians. The forms can be paper based or electronic on personal-data assistants. Data from either method of collection are entered into a centralized database for storage and analysis. The system uses stringent definitions, thereby ensuring consistent data from the collectors. If animals are observed with clinical signs then the clinical decision tree (Fig. 3) (Decision Tree Writing Group, 2006) is used to help make a plan to intervene or to continue monitoring.

2. *Interventions* The clinical decision tree was developed to help clarify the somewhat ambiguous health-care policy of 'veterinary intervention will occur only when the problem is human-induced, such as an injury caused by a snare, or when the condition threatens the gorilla's life'. The decision to intervene is influenced by age, gender, risk benefit and, unfortunately, even tourist pressure on the host-country conservation authorities. Interventions are limited in scope because the gorillas are not removed from the habitat for health care and young (age) gorillas need to be able to return to the group before night fall. Interventions fall into two categories (1) without or (2) with anaesthesia. The first involves darting the animal with a treatment drug deemed appropriate for the clinical signs observed and past experience. The second involves darting the animal with anaesthesia or an immobilizing drug. At the time of writing, the project used an injectable ketamine–metatomidine combination that creates a smooth quick onset, *c*. 40 minutes of restraint, and analgesia for sample collection and minor treatment. If longer or deeper anaesthesia is required, then the injectable anaesthetic is supplemented with isoflurane, an inhalation anaesthetic. The advantage of this injectable ketamine–metatomidine combination is that the metatomidine is reversible for quicker recovery times. While the animal is anaesthetized, samples are taken for (1) diagnostics and disease titres that will reflect the health of the individual and its group, and (2) the biological resource centre and other approved research projects. Treatment is administered after evaluation of the clinical signs and physical examination. The procedure is not without risk to humans or the animals involved. Risk is minimized by proper training and preparation of personnel and equipment. The veterinarian attempts to dart the animal away from the dominant male (silverback) and at close range for an accurate placement of the dart. Although people have been bitten during the procedures, the incidence is low and the wounds, to date, have been minor. Since 1998, 41 animals have been anaesthetized with no associated deaths (MGVP Inc., unpubl. data). Before that time, 26 animals were anaesthetized between 1986 and 1997 with four associated deaths, the last of which occurred in 1989 (Sleeman *et al*., 2000). Although either form of intervention causes disruption to the group, there have been no detrimental long-term effects observed.

The most common cause for intervention without anaesthesia is respiratory problems. Interventions with anaesthesia usually occur after injury from snares and when more advanced respiratory illness has been observed. Although the measure for success of the interventions is subjective, it is considered by most involved to be a beneficial process, both from an individual animal-welfare aspect and at the population

level. Health care for the gorillas remains the main focus of the project but other wildlife is treated if time and resources allow.

MGVP Inc., runs the Eastern Gorilla Interim Quarantine Facility that houses one Mountain gorilla and six Eastern lowland gorillas. MGVP Inc., is responsible for the health of confiscated gorillas and, with the Dian Fossey Gorilla Fund International (DFGFI), for their management. The reason for the existence of the Interim Quarantine Facility is that, to date, no orphan Mountain gorilla appear to have been released back to the wild successfully. This group will be held until the animals are 7–8 years of age when in nature there would normally be new recruitment into groups. The orphan Eastern lowland gorillas were brought from DRC to be reared with the Mountain gorilla and they will be returned to DRC when the Mountain gorilla is released. A more permanent solution for orphan primates and apes within the region is being developed [e.g. Pan African Sanctuary Alliance (PASA): www.panafricanprimates.org].

3. *Post-mortem examinations* Several new insights were revealed after a review of the first 100 recorded mortality results (Nutter *et al*., 2005). Trauma is the leading cause of death in all age groups. In infants this tends to be the result of infanticide, a natural behavioural occurrence that would not warrant interference from MGVP Inc. Within the juvenile and adult age groups, trauma can be the result of gorilla–gorilla aggression but is more often a direct result of injury caused by snares, occasional poaching for infants and, very rarely, gorilla bushmeat. MGVP Inc., plays a large role in treating animals that have sustained wounds from snare activities but the main reduction in losses from these causes needs to come from law enforcement and anti-poaching patrols.

The second most prevalent cause of death in all age groups is pneumonia. It can be argued that respiratory-disease outbreaks are a natural phenomenon but two factors suggest that there are human-induced components. First, the number of medically unscreened tourists that visit the groups with the potential of spreading upper-respiratory viruses to which the gorillas are susceptible; second, the fact that the gorillas have had much of the lower-altitude portions of their habitat taken away for pyrethrin farming and now inhabit colder and moister regions. The results of the mortality review suggested a more aggressive intervention plan should be followed for respiratory-disease cases. This includes immobilization of mothers either to treat both mothers and infants when both individuals are showing clinical signs of pneumonia or to remove a dead infant for necropsy in the face of a potential outbreak of pneumonia.

Other causes of mortality found during the review have significantly lower prevalence rates or are situations that would be difficult to correct under field conditions. An example is old-age arthritic changes that may cause problems for an individual when it is trying to keep-up with the group.

Necropsies on other species in the park can be rewarding, particularly on other species of primates because different species of primates sharing the same habitat are more likely to have similar health issues than the same species of primate across fragmented habitats (Wolfe *et al*., 1998).

Humans The human population surrounding the Virunga Massif is one of the densest in all of Africa (*c*. 500 people sq km^{-1}) (World Bank, 2002). This, combined with agricultural activities, a poor level of hygiene in local communities and sharp park boundaries (lack of buffer zones), increases the potential for transmission of infectious disease into the park and the gorilla population.

There are four segments of the human population that play a role in gorilla health. First, the military for whom little health control or information can be obtained, although military activities are known to occur in the gorilla habitat. Second, members of the community, who either enter the park illegally or have contact with gorillas that leave the park as part of their daily routine. Hygiene education and conservation

education are being carried out within the communities by other NGOs [The Gorilla Organization, International Gorilla Conservation Programme (IGCP) and DFGFI]. Although outside the scope of MGVP Inc., at the time of writing the project was actively searching for collaborators to fill voids in conservation-related public-health issues.

Third, tourists, from Europe, North America and Asia have the potential to transmit new pathogens to the local human population and to the gorillas. Foreign tourists may also have been exposed to aerosol-transmitted diseases during long plane trips before arriving in gorilla habitats. Such tourists can be within 7 m of the Mountain gorillas in as little as 30–40 hours of leaving their country of origin. Although tourists are requested not to go gorilla viewing if ill, they will often hide signs of illness and trek to see the great apes because of prepaid schedules (Adams *et al*., 1999). Travel and booking agents, trackers and guides, all are educated to present to tourists a series of gorilla-viewing rules developed to minimize the risk of transmitting disease (Cranfield *et al*., 2002). Tourists and their potential role in transmitting novel diseases to the trackers and guides is potentially a major critical-control point for reducing the risk of human-disease transfer within the gorilla population.

The last human population to be considered as having a role in gorilla health, and the one with the greatest contact with the gorillas and tourists, consists of conservation personnel. This is a defined group of people who have daily exposure to the gorillas and the tourists. This group appears to be the most cost-effective and efficient way to provide human-health interventions in a preventive fashion. The MGVP Inc., Employee Health Program (EHP) was established in June 2001, in collaboration with the Office Rwandais du Tourisme et des Parcs National (ORTPN), and DFGFI with support from the Rwandan Ministry of Health. The goals of the EHP are to assess and improve the health status of the trackers, guides, researchers, veterinarians and other employees of the organizations working in the Parc National des Volcans (ORTPN, DFGF, IGCP and MGVP Inc.), thereby reducing the risk of zoonotic disease transmission between the gorillas and employees. Improving the health status of the employees reduces the number of sick days, increases on-the-job productivity, improves morale and can help enhance the overall health of the families of employees. The programme is used to identify critical-control points for prevention of disease transmission between the Mountain gorillas and employees and to develop recommendations and guidelines for researchers, trackers and their families. Health education during these programmes consists of training sessions and provision of literature.

The components of the EHP include a survey questionnaire, medical history, a clinical examination, diagnostic tests, and necessary treatments and vaccinations. All of the information gathered is entered into relational databases to be used for (1) tracking employees who need follow-up for a health problem; (2) developing an epidemiological profile of employees and factors potentially affecting the health status of employees over time (e.g. occupational, social); (3) assessing risk of disease transmission between employees and Mountain gorilla populations quantitatively; (4) indicating the health profile of the general population in the surrounding area. The programme is now implemented at three locations in two of the three countries and includes *c*. 450 people. The EHP has identified cases of infectious disease in humans that are zoonotic, as well as some that are not, such as AIDS. Some of the first people in Rwanda on HIV drug treatment were identified through this EHP. Other incidental but interesting findings, which, through treatment, have improved the lives of the participants, are high-blood pressure, diabetes and the need for eye glasses (Ali *et al*., 2004).

Domesticated animals The third component to the 'one health' approach to conservation is the domesticated animals that surround the park. They have contact with the gorillas by both the gorillas entering the farmland and

the livestock entering the park. This has decreased in the last few years owing to the erection of a stone wall along most of the park boundary. Indirectly, the livestock and the gorillas have possible exposure to pathogens through Forest buffalo *Syncerus caffer nanus* mingling with the cattle on the pastures and then often using the same trails through the forest as the gorillas. The aim of improving the health of domesticated animals is twofold; first, to reduce the risk of transmissible diseases to the wildlife of the area, and second, to increase the productivity of the local livestock. This should reduce the need for local people to enter the park for food and should raise the local standard of living, and thereby increase the standard of health care for families.

Domesticated-animal health care is another area where MGVP Inc., does not have the resources to implement a total programme, but it facilitates collaboration by other institutions and encourages post-graduate activity in the area. Recently, it was noted by the villagers around the park that dogs were entering the Rwandan portion of the Virunga Park. There were two human deaths attributable to rabies around another wildlife park in Rwanda (anecdotal). The over 1200 unvaccinated dogs and cats in the region were a health risk to the public and gorillas. Through district veterinarians and MGVP Inc.'s Rwandan field veterinarian, a rabies vaccination programme was implemented to reduce this problem. This is an important start to reduce a zoonotic disease, but a collaborator is needed for a more in-depth small-animal health programme that will address more animal-welfare and animal-population issues.

IMPACT™

For the first 10 years of the project, health data collection was completed by the hard-working, enthusiastic, but often compromised, wildlife veterinarians. However, records had to be in hand-written format, often without the use of consistent medical terminology. Some were consistent but much was lost when the Volcano Veterinary Center at Kinigi was partly destroyed during the 1994 genocide. All surviving notes were later put into Microsoft Word and, still later, coded and entered into a database. The data were accurate but not

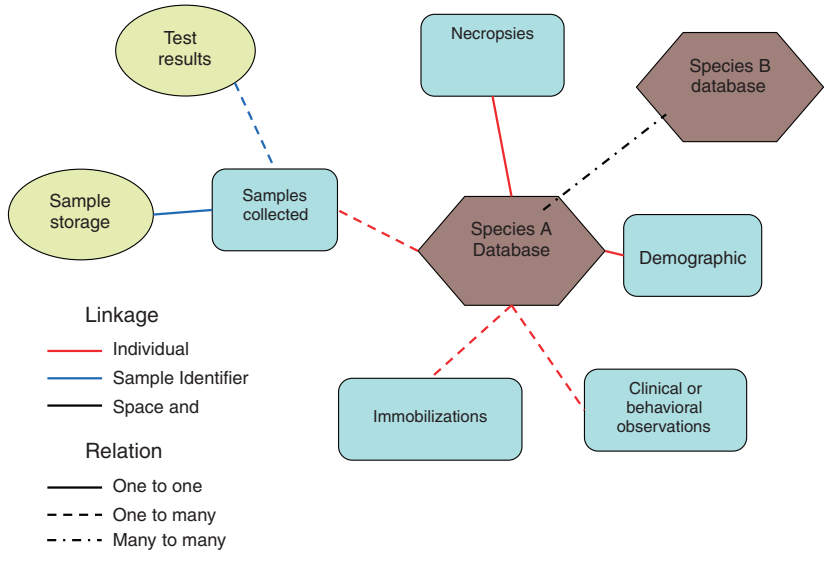
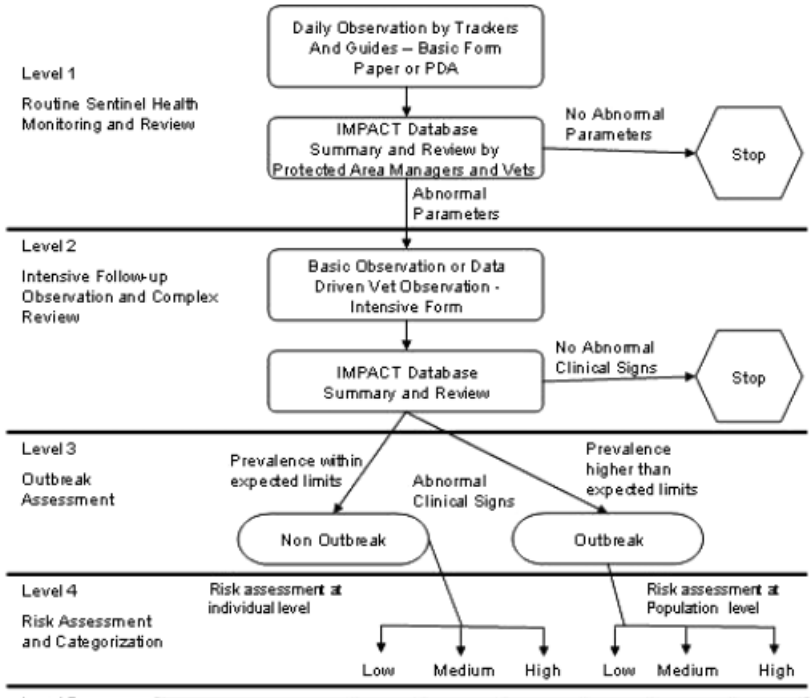


Fig. 2. IMPACT™ health-monitoring system database schematic of relations between existing and future database tables. IMPACT, Internet-supported Management Program to Assist Conservation Technologies.

necessarily consistent and lacked denominators; for example, describing only ill animals and not-ill animals in relation to the number of animals present. Later, the project utilized MedARKS, a system designed for captive wildlife. However, this system could not handle all the databases needed for MGVP Inc.

To have an effective integrated programme, there was a need for a cohesive database system that would manage disparate



Action	Low	Medium	High	Low	Medium	High
Immobilization	N/A	±	+	N/A	±	+
Diagnostics a) invasive b) non-invasive	 N/A ±	 ± ±	 + +	 N/A ±	 ± ±	 + +
Treatment	N/A	±	+	±	±	+
Continued Observation	±	+	+	+	+	+
Outside Help	N/A	N/A	±	N/A	± reg	reg ± inter
Action Plan	N/A	N/A	+	±	+	+
Preventive Action	N/A	±	±	±	±	+
Reporting	PA + PD	PA + PD	PA + PD	PA + PD	$ + SH + PH	$ + Approp Inst.
Export Permits	N/A	N/A	N/A	N/A	±	+

Fig. 3. Flow chart of the clinical response decision tree for Mountain gorillas *Gorilla beringei beringei***: N/A, not applicable; ±, decision on individual case basis; reg, regional or in-country veterinarians can handle situation; inter, international help needed; PA, protected area authority; PD, MGVP Inc., project director; PH, public-health official; SH, stakeholders; S, subsequent groups; Approp Inst., appropriate institution (such as National Institutes of Health or Centers for Disease Control and Prevention).**

data. IMPACT™ was developed to handle multiple databases that can relate to a variety of species. While this programme was created specifically to deal with the many aspects of gorilla data being collected, it soon became apparent that it had much larger potential. Most, if not all, conservation programmes utilizing similar databases could be served by this programme, with minor changes (Fig. 2). It is already being used by the conservation personnel of Gombe Park for the Chimpanzees *Pan troglodytes* and by the Wildlife Conservation Society, NY, USA, for Western lowland gorillas *Gorilla gorilla gorilla*.

The first module of IMPACT™ was developed to link tracker and guide health-monitoring data to veterinarian, park managers and others through the Internet. The system analyses the data to indicate the need for an intervention and/or whether there is an outbreak (higher then normal prevalence of clinical events) and a need for a contingency plan to go into effect (Fig. 3). The data can be retrieved from a password-protected system at the IMPACT™ website (http://mgvp.cfr.msstate.edu). Figure 3 shows how information collected using the IMPACT™ system fits into a decision tree to aid the veterinarians and protected-area mangers to make information-based health decisions. The system keeps consistent and reliable clinical records and deals with the large and complicated task of monitoring sample collection, aliquoting, storage, distribution and test results.

CONCLUSION

MGVP Inc., will continue to evolve with diverse health-care partners until the model seen in Fig. 1 has been achieved and the risk of disease to the Mountain gorillas has been reduced to the lowest practical level. Although many of the partners involved will be human and domestic-animal medical practitioners, it is the wildlife veterinarian who will have the most pivotal role in the process.

ACKNOWLEDGEMENTS

The authors would like to thank Drs Christopher Whittier, Felicia Nutter, Dominic Travis, Lynne Gaffikin, Jean-Bosco Nizeyi, Jean Fleliz Kinani, Eddie Kambole, Jacques Iyanyi and Nina Storch for their help with the preparation of this manuscript, and the Office Rwandais de Tourisme et des Parcs Nationaux (ORTPN), Institut Congolais pour la Conservation de la Nature and Uganda Wildlife Authority for their assistance. We would also like to acknowledge the previous field staff and researchers: James Foster, DVM, 1986–1988; Barkley Hastings, DVM, 1988; Susanne Anderson, BVSc, 1988–1989; Elizabeth J. Macfie, DVM, 1989–1993; H. Melvyn Richardson, DVM, 1992–1993; John E. Cooper, FRCVS, 1993–1995; Jonathan Sleeman, MRCVS, 1995–1997; Kenneth Cameron, DVM, 1997–1999; Ute Eilenberger, DVM, PhD, 1999–2001; Antoine Bayra Mudakikwa, DVM, 1995–2002; Jo Anne L. Garbe, DVM, JD, 2001–2002; John Bosco Nizeyi, DVM, 1993–present, Innocent Rwego, DVM, 2001–2003.

REFERENCES

Adams, H. R., Sleeman, J. & New, J. C. (1999): Medical survey of tourists visiting Kibale National Park, Uganda, to determine the potential risk for disease transmission to chimpanzees (*Pan troglodytes*) from ecotourism. *Proceedings American Association of Zoo Veterinarians* **1999:** 270–271.

Ali, R., Cranfield, M. R., Gaffikin, L., Mudakikwa, T., Ngeruka, L. & Whittier, C. W. (2004): Occupational health and gorilla conservation in Rwanda. *International Journal of Occupational Environmental Health* **10**(3): 319–325.

Cranfield, M. R., Gaffikin, L., Sleeman, J. & Rooney, B. A. (2002): The mountain gorilla and conservation medicine. In *Conservation medicine: ecological health in practice*: 282–290. Aguirre, A. A., Ostfield, R. S., Tabor, G. M., House, C. & Pearl, M. C. (Eds). New York, NY: Oxford University Press.

Decision Tree Writing Group (2006): Clinical response decision tree for the mountain gorilla (*Gorilla beringeii*) as a model for great apes. *American Journal of Primatology* **68**(9): 909–927.

Garner, K. J. & Ryder, O. A. (1996): Mitochrondrial DNA diversity in gorillas. *Molecular Phylogenic Evolution* **6:** 39–48.

Graczyk, T. K., DaSilva, A. J., Cranfield, M. R., Nizeyi, J. B., Kalema, G. A. & Pieniazek, N. J. (2001): *Cryptosporidium parvum* genotype 2 infections in free-ranging mountain gorillas (*Gorilla beringei* spp) of the Bwindi Impenetrable National Park, Uganda. *Parasitology Research* **87**(5): 368–370.

Graczyk, T. K., Nizeyi, J. B., DaSilva, A. J., Moura, I. N. S., Pieniazek, N. J., Cranfield, M. R. & Lindquist, A. H. D. (2002): A single genotype of *Encephalitozoon intestinalis* infects free-ranging gorillas and people sharing their habitats in Uganda. *Parasitology Research* **88**(10): 926–937.

Graczyk, T. K., Nizeyi, J. B., Ssebide, B., Thompson, R. C., Read, C. & Cranfield, M. R. (2002): Anthropozoonotic *Giardia duodenalis* genotype (assemblage) a infections in habitats of free-ranging human-habituated gorillas, Uganda. *Journal of Parasitology* **88**(5): 905–909.

IUCN (2006): *2006 IUCN red list of threatened species*. Gland and Cambridge: IUCN. http://www.iucnredlist.org/

NIZEYI, J. B., MWEBE, R., NANTEZA, A., CRANFIELD, M. R., KALEMA, G. R. & GRACZYK, 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**(6): 1085–1088.

NIZEYI, J. B., CRANFIELD, M. R. & GRACZYK, T. K. (2002): Cattle near the Bwindi Impenetrable National Park, Uganda, as a reservoir of *Cryptosporidium parvum* and *Giardia duodenalis* for local community and free-ranging gorillas. *Parasitology Research* **88**(4): 380–385.

NIZEYI, J. B., SEBUNYA, D., DASILVA, A. J., CRANFIELD, M. R., PIENIAZEK, N. J. & GRACZYK, T. K. (2002): Cryptosporidiosis in people sharing habitats with free-ranging mountain gorillas (*Gorilla gorilla beringei*), Uganda. *American Journal of Tropical Medicine and Hygiene* **66**(4): 442–444.

NUTTER, F. B., WHITTIER, C. A., CRANFIELD, M. R. & LOWENSTINE, L. J. (2005): Causes of death for mountain gorillas (*Gorilla beringei beringei* and *Gorilla beringei* undecided) from 1968–2004. In *Wildlife health in a shrinking world: ecology, management and conservation. Wildlife Disease Association international conference, June 26–July 1, 2005, Cairns, Queensland, Australia*: 200–201. Baerc, K. (Ed.). Lawrence, KS: Wildlife Disease Association. [Abstract.]

PICKRELL, J. (2004): *Africa's mountain gorillas rebound, says new census*. Washington, DC: National Geographic Society. http://news.nationalgeographic.com/news/2004/01/0127_040127_gorillas.html

POKRAS, M. A., TABOR, G., PEARL, M., SHERMAN, P. & EPSTIEN, P. (2000): Conservation medicine: an emerging field. In *Nature and human society. The quest for a sustainable world*: 551–556. Raven, P. H. (Ed.). Washington, DC: National Academy Press.

SLEEMAN, J. M., CAMERON, K., MUDAKIKWA, A. B., NIZEYI, J.-B., ANDERSON, S., COOPER, J. E., RICHARDSON, H. M., MACFIE, E. J., HASTINGS, B. & FOSTER, J. W. (2000): Field anesthesia of free-living mountain gorillas (*Gorilla gorilla beringei*) from the Virunga volcano region, Central Africa. *Journal of Zoo and Wildlife Medicine* **31:** 9–14.

WALLIS, J., MUNN, J. & REYNOLD, V. (2002): Snare injuries in chimpanzees: collateral damage of the bushmeat trade. *American Journal of Primatology* **57**(S1): 1–20.

WERIKHE, S., MACFIE, L., ROSEN, N. & MILLER, P. (Eds) (1998): *Can the mountain gorilla survive? Population and habitat viability assessment workshop for* Gorilla gorilla beringei, *Kampala, Uganda, 8–12 December, 1997*. Apple Valley, MN: Conservation Breeding Specialist Group.

WHITTIER, C., NUTTER, F. B. & CRANFIELD, M. R. (2005): Seroprevalence of infectious agents in free living mountain gorillas (*Gorilla beringei* ssp). In *Wildlife health in a shrinking world: ecology, management and conservation. Wildlife Disease Association international conference, June 26–July 1, 2005, Cairns, Queensland, Australia*: 291. Baerc, K. (Ed.). Lawrence, KS: Wildlife Disease Association. [Abstract.]

WOLFE, N. D., ESCALANTE, A. A., KARESH, W. B., KILBOURN, A., SPIELMAN, A. & LOL, A. A. (1998): Wild primate populations in emerging infectious disease research: the missing link? *Emerging Infectious Disease* **4**(2): 149–158.

WORLD BANK (2002): *The little red data book* (4th edn): 181. Washington, DC: The World Bank. http://www.worldbank.org.

Manuscript submitted 6 September 2006; revised 11 January 2007; accepted 17 April 2007