

## Section 2

### Approaches—On the Ground



# Chapter 2

## Conservation Medicine for Gorilla Conservation

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Wildlife Conservation Society (WCS)

### 1. Introduction

This chapter will discuss historical, present, and future approaches of veterinary science and medicine in the context of gorilla conservation and conservation medicine. The emphasis is placed on the mountain gorilla due to the intensity of study this subspecies has received. Disease is now ranked the third most serious threat to the sustainability of gorilla populations in general, and in areas of protected habitat it is considered the primary threat.

There is greater interaction, contact, and confrontation with wildlife as human populations, with their associated agricultural practices and domestic animals, grow and consume and/or utilize more natural resources. Global environmental changes and this human expansion have led to the emergence of new diseases and new host susceptibility to old pathogens as species that have never come into close contact before are forced into novel relationships (Wolfe *et al.*, 1998). This phenomenon presents increased challenges to health management (conservation medicine) of wildlife and their habitats.

Conservation medicine can be defined as the medical practice that seeks to ensure ecological health and well-being of a defined habitat. In terms of veterinary science, and medicine in a broad sense, it is the study of the pathogen flow and interventions to reduce pathogen exchange among wildlife, humans, and domestic animals. Since disease pathogens play important ecological roles, a particular medical problem in a species of interest must be viewed in the context of conspecifics and habitat quality in order to define health for an ecosystem. Veterinary input into such conservation efforts has expanded greatly in the last decade (Karesh and Cook, 1995).

Several key aspects of medicine with respect to gorilla conservation are discussed in this chapter, including:

- A) The different philosophical approaches to clinical and preventive veterinary management of large gorilla populations such as *Gorilla gorilla gorilla* and *Gorilla beringei graueri*, and the small populations of *Gorilla gorilla delhi* and *Gorilla beringei beringei*.

- B) The wildlife/domestic, animal/human interface and the need for collaboration between the wildlife veterinarian, local practitioners, and human health experts.
- C) The consequences of recent human interactions with gorilla populations, including habituation, poaching and resulting orphans, and ecotourism.
- D) The modern approaches to collection, storage, and analysis of biological samples.
- E) The development of information systems, including electronic databases, that will allow the rapidly expanding medical knowledge of gorillas to be analyzed and integrated into computer modeling to aid with sound management and evidence-based policy formation.

## 2. Health Objectives Common to all Gorilla Subspecies

Health objectives common to all gorilla subspecies include:

- A) The development of contingency plans involving all the conservation partners to reduce the potential devastating effects of disease epidemics in gorillas and other wildlife populations.
- B) The methodical and consistent collection of baseline health data and information (such as the prevalence and incidence of diseases present in a population) so future health changes, due to human activities or other factors, can be evaluated.
- C) The development of research programs and data analysis to gain a clear understanding of the relationship between human and domestic animal health and the health of gorillas and other wildlife in different habitats.
- D) The formation of a professional and holistic collaborative approach among conservation partners and government agencies to address health concerns.

## 3. Health Management and Conservation Medicine Practices for Gorillas

### *3.1. Large Versus Small Gorilla Population Health Management*

The health management of large populations of wildlife, such as gorillas, requires a baseline understanding of diseases and health abnormalities present in populations that appear to be viable and demographically healthy (Karesh *et al.*, 1998; Kilbourn *et al.*, 2003). In the larger populations, such as the western lowland gorilla, where management focuses on the population more than the individual, data is gathered via both opportunistically and

proactively scheduled sample collections that may be either noninvasive or invasive in nature. The benefit of acquiring the samples is worth the risk to the population. Invasive samples are gathered from clinically normal individuals for the sole purpose of data that reflect the health status of, and allow for informed management of, the overall population. Preventive health programs are based on this information and directed to protect the health and viability of the populations as well as the ecosystem. Conversely, the management of small populations, such as the mountain gorilla, where each individual is an integral part of the population's sustainability, proactive sampling is very restricted with respect to invasive collection of samples (Cranfield *et al.*, 2002). Limited data on healthy individuals is gathered only opportunistically. Most of the data from invasive sampling are from sick or injured individuals that may not be representative of the overall population. With the mountain gorillas, in contrast to the western lowlands, a large percentage of time and resources is spent monitoring and treating individual animals to enhance the population numbers.

### 3.2. *Health Management of the Western Lowland Gorilla*

For western lowland gorillas, a regional, standardized approach is being implemented in the Central African Republic, the Republic of Congo, and Gabon. To date, dozens of park guards, park managers, and researchers have been trained in concepts of infectious diseases, basic health surveillance methods, record keeping, and preventive medicine. Extensive protocols standardizing invasive and noninvasive testing procedures, record keeping, monitoring techniques and procedures, and human health-related issues have been distributed to sites with western lowland gorillas (full protocols are available at <http://www.fieldvet.org/>). Community outreach programs, including education on the risks of disease transmission between animals and humans, have begun at some sites and are being expanded to other areas. Several months following these educational programs, surveys conducted in these villages suggested that the hunting and consumption of non-human primates declined (Karesh, personal communication). Interventions involving immobilizations and physical examinations of "normal" western lowland gorillas have provided initial baseline information on their exposure, or lack of exposure, to common infectious diseases. "Apparently normal" gorillas had a wide variety of exposure to infectious agents, including yellow fever virus, *Treponema* sp. (Yaws), influenza virus, etc. (WCS, unpublished data). Knowledge of exposure to seemingly less significant viruses can have very meaningful implications. If an outbreak develops, knowing which infectious agents healthy gorilla populations have been exposed to prior to the outbreak may help to rule out these agents as a cause of concern. All western lowland gorillas tested had antibody titers to adenovirus. This information from banked serum samples has been critical in evaluating the potential for using an Ebola hemorrhagic fever virus (EHFV) vaccine in development that is on

adenovirus vector (i.e., the gorilla's immune systems may neutralize the vaccine, making it ineffective).

### 3.3. *Health Management of the Mountain Gorilla*

The small populations of mountain gorillas in the Virungas and the Bwindi Impenetrable Forest, number approximately 300–350 individuals in each habitat. They are the most intensely studied and habituated gorilla populations, with the highest density of humans and associated land use around their very limited habitats. Studies have shown that each individual's genetic makeup is extremely important to the viability of the population (Garner and Ryder, 1996). The approach to conservation medicine with the mountain gorillas is different from other gorilla populations because of the closely monitored activities and health of gorilla individuals, and the fact that habituated individuals can be clinically managed with less risk to the veterinarian or animal than is the nonhabituated gorillas. The Mountain Gorilla Veterinary Project (MGVP, Inc.) approaches health management from both a population management level as well as individual clinical cases.

MGVP, Inc. was started in 1986 at the request of Dian Fossey, who had seen the mountain gorilla population decline in the Virungas to an estimated 260 individuals, in part due to human-induced snare wounds, trauma, and illness. MGVP, Inc., is thought to be the first health care initiative responsible for *in situ* clinical care of individuals of a wild population through its clinical medicine and pathology programs. It has been credited as one of the efforts responsible for the increase in the number of gorillas in recent years (Butynski and Kalina, 1998). Veterinarians routinely visit habituated groups to evaluate clinical signs and occasionally treat animals when life-threatening or human-induced health problems occur. Biological samples are collected invasively only during interventions for health problems, and therefore represent a biased subset of the population, making it difficult to establish normal baseline health parameters.

### 3.4. *Clinical Medicine of Mountain Gorillas*

Few, if any, wildlife species are given the degree of clinical veterinary care that habituated mountain gorillas receive. While clinical medicine is not without technical, logistical, and political difficulties, it is generally feasible with habituated gorillas. The interests of the multiple stakeholders involved in gorilla conservation, combined with the widely accepted tenet of not interfering with natural processes, often complicate or even abrogate possible clinical procedures. However, well-designed policies and protocols, proper contingency planning, and excellent communication allow for successful clinical interventions when deemed necessary.

Once decisions are agreed upon, the inherent difficulties with obtaining and organizing equipment, transportation, and personnel, which are true of any clinical wildlife procedure, must be overcome. In addition, the rugged habitat, unpredictable climate, and political insecurity in most gorilla range countries make field procedures more difficult. For established projects like the MGVP, Inc., most of this preparation has become routine, but individual procedural preferences and assistant personnel instructions should always be clearly communicated or reinforced before every procedure. Moreover, it is impossible to fully predict or anticipate the exact situation an intervention team will encounter with wild gorillas, and all parties must, therefore, maintain a fair degree of flexibility.

There are two broad categories of interventions: those involving immobilization of a gorilla or gorillas, and those in which gorillas are not immobilized. The first category obviously encompasses procedures requiring hands-on veterinary care, like snare removals or surgical wound treatment, as well as rare events, like obtaining samples to confirm certain diagnoses. Occasionally, female gorillas have to be immobilized for procedures involving their infants. This category would also include routine examinations and sample collection for background data and sentinel health monitoring that have been discussed for other gorilla populations. Anesthetic procedures usually carry a higher number of risks to both the gorillas and the people involved and are therefore avoided when non-immobilization methods are possible. Situations that might allow nonimmobilization interventions include treatment of various infections (e.g., bacterial upper respiratory infections or parasitic skin infections) or very rarely for prophylactic protection from certain diseases by vaccination (e.g., measles). These procedures are dependent on the ability to deliver antibiotics, antiparasitics, or vaccines by remote injection with darting equipment. It must be kept in mind that these situations usually require a measure of certainty of the diagnosis as well as the safety of the agents used and are therefore commonly follow-up procedures after gorillas have been previously immobilized and samples have been analyzed.

Regardless of the exact nature of the procedure, virtually all interventions involve darting at least one gorilla, either with an immobilization agent or a treatment drug. Proper and safe darting requires a fair degree of experience with gorilla behavior and should always involve the human personnel who best know the individual gorillas involved. It is usually preferable to dart the target gorilla when it is at least somewhat isolated from the others, though this is unfortunately not always possible. Most of the agents chosen for use are designed for intramuscular injection, wide margin of safety, quick inductions, and recovery. Because doses can be large and dart accuracy variable, darts are usually aimed at the large muscle groups in the upper arms and legs or sometimes the lateral back muscles if the gorillas are large enough. It cannot be overstated that many gorillas can and will react aggressively when seeing even a small dart gun barrel, and all parties must be for such

reactions. Likewise, gorillas will defend group members, especially when they are ailing, falling under the effects of immobilization agents, or being approached or handled by people. Therefore, part of the immobilization team will be dedicated solely to driving and keeping away any uninvolved gorillas.

Because immobilizations are rare events and there is little historical data on gorilla baseline health, these procedures are usually used to the fullest extent for diagnostic specimen collection. Routine protocols involve collection of blood, fecal, urine, and hair samples. In some cases, skin scrapings and/or biopsies are obtained along with any apparent ectoparasites. When timely analysis is possible, bacterial culture swabs are collected from wounds or abnormal discharges and exudates and sometimes from throats or noses to document normal flora. Portable anesthetic blood monitors, blood chemistry analyzers, and field microscopes can provide some analysis during interventions, and advances in immunogenic and molecular detection systems show promise for detection for limited disease agents. In general, however, complete diagnostics cannot be performed in the field. In the cases of snare removals or wound treatments this information is usually ancillary. Biological samples from individual gorillas help in three ways: 1) to diagnose the immediate clinical problem, 2) to assess the health status of the group from which the individual's samples have been taken, and 3) to bank for future research to monitor the health status of the population over time and events (Lehn, Chapter 6, this volume).

Bacterial cultures and antibiotic sensitivities would be beneficial for antibiotic treatment decisions on severely infected wounds or respiratory infections, but since multiple treatments per day or even daily treatments are impractical, the logistics dictate the use of long-acting antibiotics where possible and limit the selection to broad-spectrum drugs anyway.

If bacterial cultures reveal agents that might not be susceptible to these drugs, tough decisions must be made on the appropriate use of antibiotic therapy. It is generally possible and practical to treat individual gorillas by darting once, or even every 3–5 days, which the long-acting drugs allow. If, however, drugs that necessitate daily dosing are required, it may be better to opt for not treating rather than risk giving improper treatment regimens that might increase bacterial resistance. In the management of previous scabies outbreaks, a similar philosophy has held true. After studying the safety of a long-acting antiparasitic in captive monkeys, it was used because it remained effective long enough to kill any parasites that hatched after 10 days. It allowed time to treat all members of the group before the effects wore off from those first treated. The gorillas were thus unable to reinfect each other, which is a potential complication of infections like mange.

From 2001 through 2005, MGVP, Inc. conducted more than 60 gorilla treatments without immobilizations (e.g., given antibiotic or antiparasitic drugs via dart without anesthetizing gorillas), 22 full immobilizations of 27 gorillas (six mothers had babies that were worked on and/or partially



sedated), and 29 necropsies/autopsies. These numbers are relatively high with respect to historical activities of the project and probably account for at least a third of the hands-on medical procedures since 1986.

Illnesses and injuries are now comprehensively and systematically monitored. Generally speaking, MGVP, Inc. observes injuries (cuts, wounds, etc.) around once a week and respiratory “illnesses” (coughing, snotty noses, etc.) about once a month and usually at a group level (e.g., many gorillas being sick). Other illnesses (e.g., scratching, scabies, diarrhea) are seen much less often, and snares are observed around 3–5/year in all four parks. These numbers will probably rise as securing and monitoring improve in DRC. While it is obvious that monitoring is important for detecting ailments and for proper follow-up on treated or sick animals, routine health monitoring is also essential to know the regular cycles and patterns of illness.

### 3.5. Pathology

#### 3.5.1. Clinical Pathology

Clinical pathology is defined as the methods and procedures of analyzing biological samples that pertain to the prevention or diagnosis of a disease and the care of patients. This analysis is particularly important when working with wildlife like gorillas because diagnoses are otherwise only possible by visual examination from a distance or physical examination under anesthesia, which can alter physiological parameters.

A very important aspect of clinical pathology is examining serum titers or antibody levels that help to define exposure to selected organisms. This may indicate the vulnerability of a population and help assess the level of risk if exposed to a particular disease. When these titers are compared with those of the human population with potential exposure to gorillas, diseases of special interest or high risk can be better defined.

The importance of serology became evident during a respiratory outbreak in 1989, when rising titers indicated measles as the pathogen and vaccination of affected populations with a measles vaccine slowed the spread of the disease (Hastings *et al.*, 1991).

#### 3.5.2. Gross Examination and Histopathology

One of the most important tools for managing a wild population, large or small, is the understanding of the causes of morbidity and mortality within that population. Data from post-mortem examinations provides much of this information. The post-mortem consists of a gross examination in the field where organs are evaluated *in situ*. With the advent of digital cameras, visual information can be easily distributed to specialized pathologists in distant laboratories for confirmation of lesions and diagnosis. Representative samples of organ systems as well as lesions are collected for histopathology

and possible culture, and toxicology. In 30–40% of the cases, the cause of death is diagnosed on gross post-mortem. Post-mortem examinations of western lowland gorilla populations are conducted by trained local field teams (for protocols, see <http://www.fieldvet.org/> and <http://mgvp.cfr.msstate.edu/mgvp/mgvp.htm>). These examinations have helped demonstrate for the first time that lowland gorillas and some duiker species were in fact dying from EHFV (Leroy, *et al.*, 2004).

Because of the intense monitoring, a high proportion of mountain gorillas that die are usually found within a 48-hour time period, which allows veterinarians to perform more informative necropsies and recover quality tissue samples. Even when the cause of death is obvious, such as a gunshot wound or severe trauma from intergroup aggression, a post-mortem can reveal incidental findings, such as subclinical infections, that can lead to management decisions affecting the rest of the gorilla population.

MGVP's pathology program (100 complete cases as of this writing; Table 2.1) has revealed trauma as the major cause of mortality in every age group. For infants, the primary type of trauma is infanticide (13/15), while for juveniles (7/9) and adults (15/16) direct or indirect poaching is the main type of trauma. Respiratory disease is the second most common cause of death and, in this data set, affects all age classes equally. Respiratory problems are the most common infectious cause of mortality, which corresponds with respiratory disease outbreaks as the major clinical problem seen with mountain gorillas (MGVP, unpublished data). Historically, MGVP field veterinarians have found that the morbidity is high and mortality is moderate. Evidence supports the clinical impression that the majority of respiratory outbreaks have a primary viral etiology that predisposes gorillas to secondary bacterial infections. Mortality from these outbreaks can be reduced by the appropriate use of antibiotics and/or vaccines. For cases in which the cause of death is undetermined (the third most common category), infants are usually

TABLE 2.1. Causes of death by age class.

Cause	Infant (birth to < 3 years)	Juvenile (3 to <10♀ and 13♂)	Adult (≥10♀ and 13♂)	% of total
Trauma	15	9	16	40%
Respiratory	8	6	10	24%
Undetermined	9	1	7	17%
Multifactorial	1		4	5%
Gastrointestinal	1	1	2	4%
Metabolic	1	1	1	3%
Cardiac			3	3%
Infectious - other			1	1%
Developmental	1			1%
Neurologic	1			1%
Parasitic	1			1%
Total	38	18	44	100%

suffering from decomposition that hampers diagnosis, and adults, especially aged individuals, frequently have multiple subclinical and/or presumably chronic processes, the impacts of which are difficult to assess in the absence of clinical laboratory data. Incomplete histology and autolysis also contributed to this category.

One of the purposes of a pathology program is to find patterns of mortality in order to effectively concentrate resources on addressing significant problems. The deaths in the mountain gorilla population have had a bi-modal age distribution, with most of the deaths occurring in the very young and very old animals (Lowenstine, unpublished data). The deaths in the older animals are often due to natural age-related, chronic problems. These problems are usually untreatable in free-ranging animals and fall outside the mission of MGVP, Inc. As with most natural animal populations and human populations with little health care, infant mortality is significant. While some causes of infant mortality can be addressed through management at a population level (e.g., decreasing poaching, minimizing infectious respiratory outbreaks), treatment of individual cases is difficult. Infant gorillas that are too small to dart safely are generally in physical contact or within arm's reach of their mother, which means that mothers need to be immobilized to examine and treat infants. The potential for other gorillas to carry off infants of immobilized mothers further complicates potential interventions. Rapid disease progression leading to sudden or peracute death is more common in infants, which often means that clinical signs are not observed or that infants die before treatment can be rendered. The possibility that the majority of infant mortality is from natural causes such as infanticide raises management issues of whether or not it is appropriate to intervene and what level of management is acceptable.

Continued investigation of gorilla morbidity and mortality through detailed post mortem examinations will improve our knowledge of the disease processes and helps to correlate these findings with ante-mortem clinical signs so that we can more effectively intervene when problems occur.

#### 4. Human Disease as a Threat to Gorilla Survival

Recent (post-1960) circumstances have increased the extent to which humans control the fate of mountain gorillas. As an example, human population growth rates in the areas in which mountain gorillas live are very high (2–3% per annum) and the population density surrounding some areas is among the highest in the world (reaching as high as 807/km<sup>2</sup> around the Virunga Mountains) (The World Bank, 2003). Animal husbandry practices of the ever-increasing local community also inevitably affect the wildlife inside the adjacent parks.

Because humans and gorillas are genetically similar, sharing over 97% of their genetic makeup, gorillas are susceptible to many human infectious

diseases (Sibley and Ahlquist, 1984). Prior to relatively recent habituation for research and tourism purposes, and encroachment of human settlements on gorilla habitat, humans and gorillas rarely spent time in close *physical* proximity. Gorillas, therefore, may represent a potentially “naïve” population (without acquired immunity) for some infectious organisms found in human populations. Organisms introduced into susceptible, naïve populations cause higher morbidity and/or mortality than in populations that have built resistance to a disease (either through endemic disease or immunization) (McCallum and Dobson, 1995). Consequently, human beings are potential carriers of infectious diseases that could have devastating effects on gorillas. With reductions in poaching and some control over cattle grazing in the protected areas, infectious disease has since been identified as one of the *major* risks to the remaining populations of mountain gorillas (Foster, 1993; Werikhe *et al.*, 1998). Infectious diseases of concern that could be transmitted from humans to gorillas (anthropozoonosis) include those spread through respiratory modes, such as measles, tuberculosis, and influenza, and diseases spread by fomites (inanimate objects) or fecal-orally, like poliomyelitis, shigellosis, mange helminthiasis and viral hepatitis (Homsy, 1999; Whittier *et al.*, 2001). Evidence supporting interspecies pathogen transmission comes mainly from studies of captive animals (Ott-Joslin, 1993). Data on disease or pathogen transmission in the wild is scant, due to the inherent difficulties of collecting data in a rigorous way that would provide more convincing evidence.

#### *4.1. Groups of Humans Posing Potential Disease Threat*

Humans who could potentially pose a health threat to gorillas can be divided into four groups, defined by their differing levels of potential exposure and the types of health interventions possible to minimize such exposure: 1) gorilla conservation workers, 2) tourists, 3) locals from communities surrounding protected areas, and 4) illegal extant populations.

##### *4.1.1. Conservation Workers*

Protected area employees include park managers and office staff, trackers, porters, guides, researchers, and veterinarians. Office-based staff likely have very limited, if any, exposure to gorillas, but in areas with habituated populations, trackers, porters, guides, and researchers may come into close physical proximity to gorillas on a daily basis. Veterinarians who provide clinical care to sick or injured individuals have less frequent but direct contact with gorillas during clinical interventions.

Providing preventive, diagnostic, treatment, and referral health services to gorilla conservation workers is a logical strategy for minimizing the risk of infectious disease transmission between this group of humans and gorillas with which many workers have daily contact. Such an occupational health

program also reduces the risk of disease among the workers, an equally important program objective. Protocols for the types of health services that should be provided to workers coming into close contact with animals are available for personnel working with captive animals in developed country settings (Silberman, 1993), and recommendations for which services should be provided to employees working with wild animals have been proposed (Nutter and Whittier, 2001).

MGVP, Inc. initiated an Employee Health Program (EHP) in 2001 in Rwanda. EHP interventions during 2001, 2002, and 2003 involved medical history taking, a clinical exam, lab tests (on sputum, feces, blood, urine), prophylactic immunization (for tetanus), prophylactic treatment with mebendazole and metronidazole (for intestinal worms), treatment for acute diseases, referral for employees with more complicated/chronic diseases, and clinical follow-up care for anyone diagnosed during one of the clinical exams.

Recent data from MGVP's Rwanda employee health program (MGVP Employee Health Group, 2004) and bio-banked mountain gorilla blood samples from Rwanda and Uganda demonstrated that there is an overlap in the viruses for which one or more individuals from the human and gorilla groups tested antibody positive. This could represent cross-reactivity for similar viruses or positivity for the same viruses in the two species. Analysis of fecal samples from employees (2001–2003) revealed that one or more employees tested positive for helminths and enteric parasites (e.g., *Ascaris*, *Trichuris*, *Cryptosporidium*, *Giardia lamblia*, and hookworm).

As part of the EHP, employees are asked questions regarding potential job-related risk factors for disease. Data from 2002 revealed that the main risk factor for testing positive for any fecal pathogenic organism was use of a pit latrine at home. Public health sanitation interventions such as ventilated pit latrines and hygiene education would likely go a long way toward reducing the potential risk of oral-fecal disease transmission between gorillas and conservation workers. Extending health program benefits to family members, especially their children, would potentially reduce risk of pathogen transmission even more as children are often the ones at highest risk for many of the infectious diseases potentially transmissible to mountain gorillas.

#### 4.1.2. Tourists

Tourism to view the gorillas first began in Uganda in the 1960s on a small scale and in Rwanda in 1978. Tourism has since become an important source of foreign revenue for mountain gorilla range countries (Butynski and Kalina, 1998), with the potential of several thousands of tourists a year visiting the gorillas. The frequent close contact by groups of tourists may increase stress, disturb gorilla behavior, and/or pose direct health risks.

A study conducted by Adams and Sleeman (1999) provides insights into the risk that this human group could pose to the health of great apes, including mountain gorillas. In that study, a self-administered questionnaire

was filled out by tourists who visited Kibale National Park, Uganda, to view chimpanzees habituated for tourism. Almost 30% (12/43) reported that they were diagnosed with one of the diseases listed recently enough to be considered infectious at the time of the chimpanzee visit. In another study involving 21 guides, trackers, and rangers in Uganda and Rwanda (Homsy, 1999), 50% of the respondents indicated that maintaining tourists at a distance of more than 5 m was the regulation most difficult to enforce (often due to the gorillas approaching the tourists). While these two studies are not representative of all tourists visiting mountain gorillas, they provide some evidence to suggest that this human group could potentially pose a health risk to the animals being visited.

A report by Homsy (1999) summarizes numerous strategies for minimizing disease risk, and the evidence base supporting these recommendations. While promotion of many of these regulations has been in effect for a while, enforcement is not always easy. Awareness-raising among tourist agents and tourists themselves via brochures is one of the various strategies being used to assist with regulation compliance.

#### 4.1.3. Local Human Communities

Gorillas have survived until recently in areas relatively inaccessible to humans. However, human settlements in many places now extend right up to the boundary of protected gorilla habitats and are expanding in unprotected gorilla habitat. The lack of sanitation services in these areas means household refuse and human waste are disposed of on-site. Trash piles or open pits and latrines (sometimes covered and sometimes not) are usually in proximity to farmland. Some gorillas that are less fearful of humans are attracted to the crops and refuse as an alternative or supplemental food source, and interactions between humans and gorillas at this intersection are increasing. This situation poses health risks to the gorilla from direct and indirect pathogen transmission (e.g., through fomites and vectors such as rats), and also potential exposure to environmental toxins and bodily injury during physical encounters. It also poses health, social, and economic risks to humans, ranging from reduced income due to crop destruction, to potential for pathogen transmission from gorilla feces or bites, to school dropouts due to the need to stay home to protect the family's crops from being raided.

Various studies support the suggestion that organisms are being transmitted among gorillas and community members living in close proximity. For example, MGVP has shown that *Cryptosporidium*, *Microsporidium*, and *Giardia* from gorillas, people, and cattle in the Bwindi area are genetically identical in the DNA sequences studied to date (Graczyk *et al.*, 2002; Nizeyi *et al.*, 2002a,b). A review of fecal studies in the *Gorilla beringei beringei*, *Gorilla beringei graueri*, and *Gorilla gorilla gorilla* indicates that some helminths and protozoa have a higher prevalence in mountain gorillas,

possibly as a result of higher local density of, and therefore exposure to humans. However, possible differences in sampling and lab testing methods must also be considered as explanatory factors. A study of scabies in gorillas in Bwindi Impenetrable National Park in Uganda (Kalema *et al.*, 1998; Graczyk *et al.*, 2000) is highly suggestive of transmission to the gorilla population from the local human community. This is further supported by the results of comparative genotyping of mites obtained from gorillas and local humans that suggest the parasites to be genetically the same (Graczyk, personal communication).

Hygiene, sanitation, and other behaviors of community members determine the degree of risk associated with this group. For long-term effects, targeted and coordinated efforts among government and NGO health, environment, and community development agencies working in the area are needed. A pilot project between MGVP, Inc. and DFGF-I in Ruhengeri, Rwanda, involving fecal testing and treatment for community members exemplifies this kind of collaborative effort.

#### 4.1.4. Illegal Activities of Local Populations

Although the habitat in which many mountain gorillas live is now protected area, humans continue to make use of the land and its natural resources, including the wildlife. The human populations near these protected areas often have reduced access to basic services, such as health care and schooling, making them some of the country's most marginalized citizens. They often still depend upon local natural resources to meet their most basic needs for food, clothing, building material, medicine, and disposable income. Hunting, therefore, still goes on illegally in the protected areas and, in addition to direct poaching, hunters potentially expose gorillas to disease from open latrines or uncovered refuse. During times of political instability, military personnel, or rebels may take refuge in or near protected areas. Thousands of refugees camped close to and accessed the park after being displaced in Rwanda in the mid-1990s. The park's natural resources also lure people from other areas of the country or neighboring countries who then illegally hunt, log trees, or collect things like plants or honey. In the process, they also potentially expose gorillas to infectious disease.

No data exist in the literature on the transmission of disease from extant populations due to the problems of monitoring illegal activities. However, because of their existence in the forest, this population presents a potential disease source. Interventions to improve the health of the whole community will help, as many in this group come from local communities. Awareness-raising about the risk of interspecies transmission with community members could increase self-vigilance and community pressure against members who illegally enter and exploit park resources. Ultimately, the latter approach is the only one that will ensure protection of gorilla populations over the long term.

## 5. Domestic Animal Disease as a Threat to Gorilla Survival

Just as gorillas are at risk of contracting transmissible diseases from neighboring human populations, associated livestock populations represent another potential source of pathogens. The intense utilization of lands bordering the protected areas allows dynamic physical and ecological interactions between livestock and mountain gorillas. Political instability in the region has contributed to inadequate routine testing, vaccination and treatment of livestock, and to cross-border movements of people, livestock, and their pathogens. Groups of mountain gorillas habituated for tourism and research in Rwanda and Uganda spend significantly more time in agricultural lands outside the park than do unhabituated groups. These forays can last from a few hours up to 8 months and result in dietary changes and reduced daily ranges (Madden, 1998; Butynski, 2001; Goldsmith, 2000; Whittier and Nutter, personal observations). Gorillas outside the park are often in proximity with grazing cattle, sheep, goats, and poultry, which puts them at risk for contracting livestock diseases either directly or via contaminated environments.

Pathogens of concern include a range of bacteria, viruses, and parasites. Previously mentioned studies have documented the presence of the gastrointestinal parasites *Giardia*, *Microsporidia*, and *Cryptosporidium* species that appear genetically identical in gorillas, cattle, and people near the border of the Bwindi Impenetrable Forest, Uganda (Graczyk *et al.*, 2002, Nizeyi *et al.*, 2002a,b). This is objective evidence that pathogens flow among these populations, and contaminated water sources may play a role in pathogen spread since all are commonly waterborne parasites. Tuberculosis and brucellosis have been devastating for wildlife populations in numerous countries throughout the world. The high regional prevalence of *Mycobacterium* and *Brucella* in central African livestock raises concern for the interactions among cattle, sheep, goats, and mountain gorillas. In Uganda and Rwanda, surveys have reported seroprevalence of brucellosis as high as 35% in cattle, and 13–35% in goats (Onkalit 1987; Akakpo *et al.*, 1988; Kabagambe *et al.*, 2001;), with no data available for sheep. In Rwanda, reported tuberculosis prevalence in cattle is 11% (Kabagambe *et al.*, 1988), with no data available for sheep or goats in Rwanda, or for any livestock in Uganda. Published data on livestock diseases is completely lacking for the Democratic Republic of Congo (DRC). Both organisms can survive for months to years in cool, humid environments like that of the Virunga Volcanoes region (Nicolletti, 1998; Bengis, 1999; Woodford *et al.*, 2002). Research is in progress to examine the prevalence of tuberculosis and brucellosis in livestock adjacent to Parc National des Volcans (Rwanda) to help evaluate the potential threat to gorillas. The risk of disease transmission between livestock and gorillas can only properly be addressed if disease prevalences in livestock are known, and if livestock and wildlife management practices can be modified if necessary.



## 6. Habituation of Gorillas for Tourism

Habituation of gorillas is the slow but increasing methodical exposure of trained trackers to unhabituated gorillas until the gorillas become accustomed to the daily visit and appear to pay little attention and show minimal aggression. With the mountain gorillas the process usually takes about a year, during which it is postulated (but not substantiated) that the gorillas are stressed and potentially more susceptible to disease. The process should be well planned and include a) an extensive health screening of the personnel before and during the habituation to minimize the exposure of the gorillas to disease, and b) the collection of biological samples from known gorillas during the process for objectively assessing the health effects of the habituation. These measures are being undertaken as DFGFI and MGVP, Inc. collaborate on new conservation efforts in the relatively undisturbed habitat of the unhabituated eastern lowland gorilla populations in DRC. Once habituated, the gorillas' exposure to humans greatly increases and veterinary activities as described elsewhere in this chapter should be undertaken.

## 7. Orphaned Ape Health Management

Young apes continue to be orphaned throughout Africa as a by-product of the bushmeat trade, a result of habitat destruction, and, to a far lesser extent, as the occasional target of poaching for private collections. A number of important geographic, economic, political, and cultural factors contribute to the complexity of this problem that are beyond the scope of this chapter and have been discussed elsewhere (Miles *et al.*, 2005).

The majority of these orphans do not survive very long after separation from their dead mothers. Those that do are usually mentally traumatized, and the even fewer that are recovered by authorities are generally physically weak, malnourished, dehydrated, and are commonly suffering from diarrhea and upper respiratory tract infections. It is critical that these animals receive veterinary/medical care for their immediate survival and that infectious disease issues are considered for their long-term placement. Ultimate outcome can be a highly political issue and will depend on individual case circumstance, but should follow the World Conservation Union (IUCN) guidelines for Placement of Confiscated Animals (IUCN, 2000) and the guidelines for reintroduction programs by IUCN/Species Survival Commission (IUCN, 2000). Even in rare cases when orphans can be quickly returned to their own natal groups, serious consideration must be given to the risk that these individuals will introduce a disease that could jeopardize the health of the population.

Regardless of the ultimate disposition, it is important that confiscated animals receive a quick health assessment, any necessary treatments, and that a proper quarantine is established for the time animals will remain in captivity.

In many cases a full examination under anesthesia is best reserved until the orphan has recuperated to a stable condition. In the meantime, treatment of obvious symptoms and provision of nutrition, hydration, and warmth are a minimum standard of care. Opinions vary, but the consensus of most primatologists, zookeepers, and veterinarians is that the physical and mental health of infant orphan apes benefits from human contact which the gorilla mothers would normally be providing the majority of their time.

A proper quarantine requires significant investment of time, energy, and other resources. The intention of a quarantine is 1) to monitor an animal for evidence of any infectious disease and to allow time for latent infections to manifest, and 2) to contain the animal in an environment that minimizes the potential exposure to any further disease agents. A proper quarantine will also provide opportunity and time for full medical evaluation and analysis of diagnostic samples.

The duration of a quarantine must consider a number of factors, including costs, logistics, personnel, space, availability of diagnostic facilities, specific disease risks, and/or diagnoses and the final intended destination of the animal. Though most captive primate facilities utilize at least a 60-day quarantine (some up to 6 months), orphan cases usually merit different considerations. A balance needs to be struck between allowing enough time to properly insure that an animal is healthy and poses minimal risk to other animals if reintroduced or placed with other captive animals, while also recognizing that apes are highly social species and may suffer detrimental effects from the long-term separation from their own species. A minimum of three weeks can be adequate for quarantine of orphans that appear healthy, receive thorough diagnostic testing, and have no risk of tuberculosis exposure. However, because it is believed to take up to 10–12 weeks from exposure to positive tuberculosis testing in young apes, prolonged quarantines may be required to fully ensure negative TB status.

Examination under general anesthetic should include thorough physical examination with particular emphasis on musculoskeletal injuries, skin condition, and upper respiratory tract function. Serial blood samples should be collected for biochemical analysis, complete blood count, and an appropriate panel of viral antigen and antibody titers. Because these orphans have been exposed to humans in areas where tuberculosis prevalence is high, tuberculosis testing is critical to prevent potential introduction of this disease into a destined population. The best TB screening test is intradermal testing with mammalian old tuberculin, and not the purified protein derivative (PPD) used for human testing. Bacterial or dermatophyte cultures, skin scrapings, and other diagnostics should be utilized when indicated, and appropriate treatments for wounds, parasitic or bacterial infections, or other ailments should be given.

An easily and often forgotten aspect of insuring the health of orphan apes is a proper human preventative health program and screening of any parties that have contact with these apes since their capture. Employee health

programs are discussed elsewhere in this chapter, and the general approach can be modified for screening specific orphan contact individuals (e.g., arrested poachers, confiscating authorities, or eventual caretakers). There are many legal and humanitarian issues involved with health screening of non-employees. At a minimum, they should receive a cursory physical exam, even if it is only visual, be questioned about childhood vaccinations, and should be screened for tuberculosis disease. Some of these individuals may have spent considerable time in very confined quarters with the captured orphans, enhancing the potential transmission of tuberculosis. The strong association between HIV status and tuberculosis infection cannot be overstated in these situations. Ideally, blood collection for viral serology screening could help eliminate a number of serious risks, though this is best done with serial titers.

Proper health management of orphaned great apes is not an inexpensive or simple matter. It should be kept in mind that any shortcomings in this management may not only impact the affected individual but could have devastating effects on the larger wild or captive populations where these orphans are placed. Proper planning, preparation, and commitment to orphan management can go a long way towards minimizing secondary effects and preserving these fragile destination populations.

## 8. Biological Resource Center

Preservation of biological specimens from gorilla populations is of great concern and interest to scientists from many disciplines such as epidemiologists, clinicians, geneticists, and conservationists. When specimens are from known individuals, it allows for potential retrospective studies on emergence of new diseases and accurate determination of changes in prevalence and biodiversity of organisms within a defined population. It also allows for the utilization of new technology as it develops to help resolve historical questions. Existing technology has the potential to store live genetic material long after individuals, if not whole populations, have died out.

Since specimens are being collected for future use when they may be tested using new technology and for yet-unspecified organisms, they are stored in a diverse array of preservatives and storage situations. For example, while fecal samples stored in formalin and polyvinyl alcohol are both good for regular floatation for helminthes, formalin is better for most immunofluorescent assay tests and polyvinyl alcohol is better for polymerase chain reaction assays (Graczyk, unpublished data).

The Mountain Gorilla Veterinary Project now has thousands of samples stored in the Biological Resource Center in Baltimore Maryland. These not only include samples from mountain gorillas, but from humans, domestic animals, and other wildlife that impact gorilla habitat. Many of the samples from the Biological Resource Center have already been utilized by researchers throughout the world for a variety of research and advanced degree projects.

## 9. Standardized Health Monitoring Systems for Gorillas

Although many versions of health monitoring systems are being utilized by gorilla conservation organizations, there is a desire and logical need to have compatibility so the data can be easily shared. Epidemiology-based information systems should be designed to provide answers to fundamental questions about beneficial or harmful effects of any programmatic or medical interventions. The information system should help to identify critical control points of pathogen flow, and computer modeling should be carried out to provide evidence-based information for sound management recommendations and policy decisions regarding great ape health management, including resource allocation.

From 1986 to 1995, MGVP, Inc. field vets routinely recorded quality but poorly standardized observational health data in field diaries. From 1995 to 2001 MGVP, Inc. utilized the American Association of Zoo Veterinarians MedARKS program designed for captive animal management data. In an effort to expand its usefulness, all of this historic qualitative data has been recently coded and incorporated into an Access database. Since then, MGVP, Inc.'s expansion of scope of work and species studied has resulted in an increase of collected and stored clinical data. To accommodate this increase of data, MGVP, Inc. developed a program called "IMPACT" (Internet-supported Management Program for Assisting Conservation Technologies). The system uses unique identifiers to link several parameters of health information. Data collection of gorilla observations (the daily baseline health monitoring of clinical signs) utilizes handheld computers or paper forms with an MGVP, Inc.-developed program. IMPACT allows for fast and easy entry of observed gorillas, with either normal or abnormal health parameters. Data easily downloaded into IMPACT greatly expands the knowledge of the prevalence of clinical signs and aids with the prognosis of present clinical cases.

IMPACT analyzes the severity, prevalence, and incidence of clinical signs to indicate a disease outbreak possibly triggering a newly developed contingency plan. The system objectively places the outbreak into a low-, medium-, or high-risk category that is reviewed and confirmed by MGVP veterinarians. The risk category and numbers of gorillas involved dictate a local, regional, or international response to minimize the negative impact of the outbreak to the gorillas.

The IMPACT system is designed to minimize data cleaning and automatically generate informational reports to share with stakeholders and partners on an ongoing basis. Since IMPACT is a web-based system, it allows field staff and other partners to have real-time access to the data and output reports, and new demographic information, such as births and deaths, can be updated and coordinated more easily. IMPACT's development is a collaborative effort between those involved in data collection and analysis, which includes epidemiologists/human health professionals, wildlife biologists, MGVP's veterinarians, Mississippi State University, and individuals from other great ape organizations.

## 10. Summary

The role of conservation medicine in gorilla conservation is evolving and expanding, as is the role of the veterinarian. Wildlife veterinarians will continue to provide basic clinical and pathological services, but the collaborative efforts of wildlife, human health, and local veterinary practitioners will need to continue at the wildlife/domestic animal/human interface to reduce the transmission of disease. Continued health monitoring and health-related research programs are needed to fill data gaps so that newly developed information systems can do epidemiological analysis. Critical control points for disease transmission need to be identified and computer models and historical data analyzed to make health recommendations to park managers. Contingency plans need to be documented and roles well defined to maximize their efficiency at reducing the negative impact if a disease outbreak should occur. Veterinarians and conservation medicine will be important tools to complement other disciplines in the long-term sustainability of gorillas in the 21st century.

## 11. Authorship

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