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Endangered mountain gorillas and COVID-19: One health lessons for prevention and preparedness during a global pandemic

Kirsten Gilardi[1] | Julius Nziza[1] | Benard Ssebide[1] | Eddy Kambale Syaluha[1] | Richard Muvunyi[2] | Robert Aruho[3] | Chantal Shalukoma[4] | Andrew Seguya[5] | Anna Behm Masozera[6]

[1]Gorilla Doctors (MGVP, Inc.), Karen C. Drayer Wildlife Health Center, University of California Davis, Davis, California, USA

[2]Department of Tourism and Conservation, Rwanda Development Board, Kigali, Rwanda

[3]Monitoring and Research Program, Uganda Wildlife Authority, Kampala, Uganda

[4]Institute Congolais pour la Conservation de la Nature, Virunga National Park, Rumangabo, Democratic Republic of Congo

[5]Greater Virunga Transboundary Collaboration, Kigali, Rwanda

[6]International Gorilla Conservation Programme, Kigali, Rwanda

Correspondence
Kirsten Gilardi, Gorilla Doctors (MGVP, Inc.), Karen C. Drayer Wildlife Health Center, University of California Davis, One Shields Ave., Davis, CA 95616, USA.
Email: kvgilardi@ucdavis.edu

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Abstract

The world's 1063 mountain gorillas (*Gorilla beringei beringei*) live in two subpopulations at the borders of the Democratic Republic of Congo, Rwanda, and Uganda. The majority of mountain gorillas are human-habituated to facilitate tourism and research, which brings mountain gorillas into close proximity of people daily. Wild great apes are proven to be susceptible to human pathogens, including viruses that have caused fatal respiratory disease in mountain gorillas (e.g., human metapneumovirus[1]). This is the result of the close genetic relatedness of humans and gorillas as species, and the structural and genetic similarity in molecular receptors that allow viruses to infect cells[2]. At the time of writing, there is no evidence that severe acute respiratory syndrome coronavirus 2, the coronavirus that causes coronavirus disease 19 (COVID-19), has infected a mountain gorilla. However, due to the significant potential for human-to-gorilla transmission, mountain gorilla range States took immediate steps to minimize the COVID-19 threat. These actions included a combination of preventive practice around gorillas and other great apes (e.g., mandatory face mask use, increased "social" minimum distancing from gorillas) as well as human public health measures (e.g., daily health/fever screenings, COVID-19 screening, and quarantines). Minimization of the COVID-19 threat also required socioeconomic decision-making and political will, as all gorilla tourism was suspended by late March 2020 and guidelines developed for tourism reopening. A consortium that collaborates and coordinates on mountain gorilla management and conservation, working within an intergovernmental institutional framework, took a multifaceted One Health approach to address the COVID-19 threat to mountain gorillas by developing a phased contingency plan for prevention and response. The aim of this paper is to describe how range States and partners achieved this collaborative planning effort, with intent that this real-world experience will inform similar actions at other great ape sites.

KEYWORDS

conservation, contingency planning, COVID-19, *Gorilla beringei beringei*, mountain gorilla, risk management

1 | MOUNTAIN GORILLAS AND ONE HEALTH

Mountain gorillas (*Gorilla beringei beringei*) are the only great ape whose numbers in the wild are increasing, with the most recent surveys estimating a minimum count of 1063 gorillas in the world (Hickey et al., 2019). Mountain gorillas live in two subpopulations: one in the Virunga Massif (comprising Volcanoes, Virunga and Mgahinga Gorilla National Parks in Rwanda, Democratic Republic of Congo, and Uganda, respectively), estimated at a minimum count of 604 gorillas (Hickey et al., 2018a) but an estimated subpopulation size of 669 (623–758) gorillas (Granjon et al., 2020); and the other in Bwindi Impenetrable National Park (Uganda), estimated to be at least 459 gorillas (Hickey et al., 2019) with an estimation of subpopulation size in progress at time of submission. Both subpopulations are considered transboundary, with protected areas contiguous across international borders (Figure 1). Population growth has been attributed to "extreme conservation" measures, including that the current range of the mountain gorilla is entirely protected and managed, and individual gorillas suffering from injury or illness benefit from in situ veterinary care (Robbins et al., 2011). The success of mountain gorilla conservation measures leading to population growth resulted in the recent down-listing of mountain gorillas from critically endangered to endangered (Hickey et al., 2018b).

Conservation success is ultimately the result of the fact that among the great apes, the mountain gorilla is also unique in the world in the extent to which the majority of the population, approximately 60%, is human-habituated to facilitate tourism (Robbins et al., 2011)—for no other great ape species in the wild is such a significant portion of the total world population coming into close daily proximity with people. While primate researchers (most famously, Dian Fossey) have been human-habituating mountain gorillas since the 1970s, habituation for tourism was first initiated in the 1980s and grew steadily thereafter (Homsy, 1999). Today, gorilla tourism generates significant revenues that fund park protection and management, and provides livelihood opportunities for communities adjacent to park boundaries (Munanura et al., 2016; Sabuhoro et al., 2017; Tolbert et al., 2018). Habituation also enables continued behavioral and ecological research that informs recommendations for management. Most importantly, habituation allows for close monitoring of all habituated gorillas, enabling daily confirmation of the presence (or absence) of individual gorillas and close observation of individual gorillas for injuries or illness, for which veterinarians (gorilladoctors.org) respond with clinical interventions that are life-saving. Protocols around mountain gorilla visitation are guided by IUCN best practice recommendations (Macfie & Williamson, 2010).

Human habituation is a double-edged sword, however. While it enables implementation of successful conservation measures, it poses conservation threats (Figure 2). Most significantly, the susceptibility of great apes to human pathogens at sites where great apes are in close proximity to people is well-described and documented. Of particular concern is the fact that human respiratory pathogens have been confirmed to cause illness in captive (Slater et al., 2014; Szentiks et al., 2009) and wild chimpanzees (e.g., Kaur et al., 2008; Köndgen et al., 2008; Negrey et al., 2019; Patrono et al., 2018; Scully et al., 2018) and in wild western lowland gorillas (Grützmacher et al., 2016). Viral respiratory infections can lead to fatal secondary bacterial infections (e.g., Chi et al., 2007; Unwin et al., 2013). The recognition that wild great apes that have close contact with people may suffer from human-borne infectious disease motivated the IUCN to publish best practice recommendations for great ape health monitoring and disease control (Gilardi et al., 2015).

Not surprisingly, mountain gorillas are proven to be susceptible to human pathogens. As far back as the initial days of mountain gorilla tourism in the 1980s, human measles was assumed to be the cause of a widespread respiratory illness outbreak in habituated mountain gorillas in Volcanoes National Park, Rwanda in 1988, based

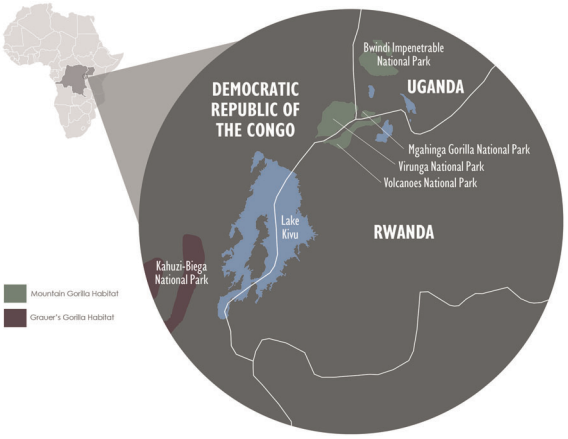

FIGURE 1 The entire world population of mountain gorillas (Gorilla beringei beringei) survive in national parks in Rwanda, Uganda, and the Democratic Republic of Congo. (Image credit: Eunah Preston for Gorilla Doctors)

FIGURE 2 Human-habituated mountain gorillas come into close proximity of people both inside and outside the parks, presenting a unique high-risk interface for potential pathogen transmission (Photo credit: Gorilla Doctors)

on clinical signs and histopathology (Hastings et al., 1991). Human metapneumovirus was determined to be the primary cause of fatal pneumonia in an adult female mountain gorilla and her infant in 2009 in Volcanoes National Park, Rwanda, during a respiratory disease outbreak that affected most individuals in the group (Palacios et al., 2011), and respiratory illness in mountain gorillas in Volcanoes National Park in 2012 and 2013 were determined to be caused by human respiratory syncytial virus (Mazet et al., 2020). Second to trauma, respiratory disease is the second most common cause of morbidity and mortality in habituated mountain gorillas, and outbreaks occur annually, often causing group-wide morbidity (Spelman et al., 2013). In this sense, One Health as the perspective that animal, human and environmental health are inextricably linked (e.g., Zinsstag et al., 2011) could not be a more accurate descriptor for the necessary approach to mountain gorilla conservation.

It was from this basis of knowledge of the uniquely significant threat that human pathogens pose to habituated mountain gorillas that mountain gorilla conservation stakeholders—for example, protected area authorities, nongovernmental organizations, researchers and veterinarians—faced the threat posed by the coronavirus disease 19 (COVID-19) pandemic. When the pandemic was officially declared by the World Health Organization on March 11, 2020, mountain gorilla conservation partners were already sounding the alarm bells, and the impetus to collectively plan for the prevention of transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes the disease COVID-19, was immediate. The governments of Rwanda, Uganda and Democratic Republic of Congo shut down gorilla tourism in the initial months of the pandemic. Herein we review the multistakeholder processes for developing and achieving prevention measures and for preparing and planning for the potential that SARS-CoV-2 could enter the parks and be transmitted to gorillas, with the intent to inform similar decision-making endeavors at great ape sites, now and in the future.

2 | APPROACH TO THE COVID-19 THREAT

COVID-19 awareness, prevention and contingency planning was initiated in February 2020 and implementation is ongoing. The focus has been on the two subpopulations of mountain gorillas living in the Virunga Massif (01°25′S/29°32′E) and Bwindi Impenetrable National Park (01°01′S/29°41′E). All planning was conducted under the auspices of the Greater Virunga Transboundary Collaboration (GVTC), which represents the governments of Rwanda, Uganda and the Democratic Republic of Congo and was established to facilitate joint and coordinated planning and management recommendations for the protected areas comprising the entire world range of the mountain gorilla. No handling or manipulation of wild gorillas was necessary for conducting this work, and therefore, there was not a requirement for Ethics Board or Institutional Animal Care and Use Committee authorizations. The steps taken to engage and mobilize stakeholders around COVID-19 and mountain gorillas can be loosely organized and described as follows:

2.1 | Notification and information-sharing among stakeholders

This work centered on the critical importance of keeping stakeholders mutually apprised of the expansion of the COVID-19 outbreak, the rapidly-evolving scientific understanding of the virus and its epidemiology, and steps each organization had taken to minimize the threat posed to mountain gorillas by the virus. Communications occurred by electronic mail, instant messaging, and conference calls. Each stakeholder worked with their teams to assess their operations and determine what modifications of practice and implementations of additional measures were necessary to address the COVID-19 threat.

2.2 | Contingency planning, for collective understanding and resolve for response

Under the auspices of the GVTC, the International Gorilla Conservation Programme (IGCP) provided technical coordination for protected area authorities and nongovernmental collaborating organizations to engage in a contingency planning process to identify phases of response, key actions for each phase, and responsible parties for implementation. An external consultant was recruited from within the region with institutional and governance expertise to thoroughly review the ability (readiness) for operationalizing the contingency plan; the review was conducted through interviews with key informants from the public sector and nongovernmental partners. Collaborating stakeholders conducted their work through multiple, iterative conference calls and contributions to drafting the contingency planning document.

3 | COVID-19 CONTINGENCY PLANNING

Notification, information-sharing and contingency planning occurred nearly simultaneously. For the purposes of this paper, the "anatomy" of COVID-19 response is presented roughly chronologically.

Before the official declaration of the COVID-19 pandemic by the World Health Organization on March 11, 2020, Gorilla Doctors issued a memorandum on February 7 to government partners on the potential risk posed by the (then so-named) 2019 Novel Coronavirus. Gorilla Doctors is a partnership between the nongovernmental organization MGVP, Inc. and the University of California, Davis that conducts health monitoring, disease research and in situ veterinary care for mountain (and Grauer's) gorillas in Rwanda, Uganda and the Democratic Republic of Congo. Their February 7th memorandum summarized knowledge to date of the viral outbreak, for example, countries affected, number of confirmed human cases, case-fatality rates, clinical presentation, and virus characteristics and transmissibility. While the memorandum acknowledged that the susceptibility of gorillas to the novel virus was unknown, it was safest to assume that gorillas could be

infected by the virus, based on the proven infectivity of human respiratory viruses for gorillas. Therefore, Gorilla Doctors urged all government and nongovernmental partners to ensure strict adherence to gorilla visitation and disease prevention best practices as established by the IUCN (Gilardi et al., 2015; Macfie & Williamson, 2010).

Gorilla Doctors issued a second memorandum on March 11, the day that the World Health Organization (WHO) officially declared the COVID-19 pandemic, after the first human case of COVID-19 was confirmed on the African continent, in the Democratic Republic of Congo. By this time, the virus was now named SARS-CoV-2. Gorilla Doctors again urged protected area authorities and nongovernmental organizations to strictly adhere to IUCN best practice recommendations, and further underscored the importance of preventing any and all direct contact between gorillas and people (e.g., tourists touching gorillas) and minimizing indirect contact with gorillas to the extent possible.

Gorilla Doctors issued a third memorandum to its partners on April 8 to confirm for partners that it was continuing to implement its mission-driven operations to monitor the health of habituated mountain gorillas and to assess any and all gorillas reported to be ill and injured. Gorilla Doctors also described the preventive measures its staff were taking to minimize the potential for transmitting the virus to gorillas, laid out its course of action should gorilla groups exhibit signs of respiratory illness, and advised what should happen if a gorilla tested positive for COVID-19.

Specifically, in the event that a gorilla or gorilla group exhibited clinical signs of respiratory illness, Gorilla Doctors stated its intent to proceed as per standard protocols for respiratory illness affecting human-habituated gorillas:

(1) Conduct a veterinary monitoring visit to visually assess the severity of clinical signs and determine the need for clinical intervention.
(2) Noninvasively collect fresh fecal samples from sick gorillas to screen for respiratory pathogens, including SARS-CoV-2.
(3) If clinical intervention is warranted, plan for the intervention in consultation with park authorities.
(4) Wear personal protective equipment (PPE: face masks, gloves, eye protection, full-sleeved clothing) when conducting a full clinical intervention that requires direct contact with the gorilla patient.
(5) Collect a full set of diagnostic samples (e.g., nasal and oropharyngeal swabs, blood) for pathogen testing, including for SARS-CoV-2.

Gorilla Doctors stated that should a gorilla test positive for SARS-CoV-2, it would notify protected authorities immediately, and recommended the following critical actions:

(1) Notify all persons who have been in close proximity of the SARS-CoV-2 positive group in the last 14 days of their potential exposure: encourage these individuals to inform their medical care team and request SARS-CoV-2 diagnostic testing; self-quarantine until tests results are available.
(2) Further minimize human proximity to the SARS-CoV-2 positive gorilla group to essential park staff and veterinarians only.
(3) Assume all gorillas in the SARS-CoV-2 positive group are infected, collect fecal samples for confirmatory testing, and monitor closely for respiratory illness; clinically intervene to deliver treatment (e.g., antimicrobials, anti-inflammatories) as necessary.
(4) Consult with park authorities to determine if the SARS-CoV-2 positive group had direct contact with other gorilla groups in the last 14 days; conduct daily veterinary monitoring of these groups for signs of respiratory illness.

Simultaneous to memoranda issued and actions taken by Gorilla Doctors, in mid-March the IGCP took the initiative to start work with protected area authorities and nongovernmental organization partners on a draft regional contingency plan for COVID-19 response, modeling the document on an Ebola Virus Disease contingency plan drafted primarily for Virunga National Park during the eastern DR Congo 2018–2020 EVD outbreak, but with input from partners in all three range states. The purpose of the COVID-19 regional contingency plan was to recognize the transboundary context and collectively agree on critical phases and the essential actions, responsible parties and necessary resources for effective response. An overarching commitment to clear lines of communication among agencies and partners and across borders was emphasized. Mountain gorilla stakeholders provided input via group editing of the draft plan posted on a file-sharing site, as well as through a series of seven teleconferences. Stakeholders shared information and discussed each organizations' activities and recommendations around COVID-19 prevention. A final draft of the *Emergent Coronavirus Contingency Plan and Resources* was endorsed by nongovernmental organization partners, and presented to the GVTC for Board approval on August 7, 2020. As well, a website for ensuring broad access to the plan was created (www.gorillaplan.org).

The Contingency Plan established an Emergency Management Team, comprised of designated representatives of the three governments, the GVTC Secretariat, the IGCP Director and the Gorilla Doctors Executive Director serving as the Board committee, and other essential members consisting of park representatives and technical and logistical support provided by nongovernmental organizations working closely with the parks. Additional consideration was given to public relations contacts. The Plan identified four key phases, each triggered by specific events:

1. Phase 0, Prepare: the default phase if no other Phase has been activated.
2. Phase 1, Prevent: activated by designation of a Public Health Emergency of International Concern by the WHO or any other global pandemic warning or determination.
3. Phase 2, Alert: initiated if cases of SARS-CoV-2 in humans or animals are declared by Wildlife Protection Agencies/Ministries

of Health and Animal Husbandry/WHO/OIE in any of the three range States.
4. Phase 3, Respond: activated by a suspected or confirmed case of SARS-CoV-2 in a mountain gorilla or other wildlife in the park, or among park staff, tourists, researchers or communities neighboring the parks.
5. Phase 4: Recovery: activated by designation of a return to a lower risk period by the regional Steering Committee.

The Contingency plan set an Action Plan for each Phase. For example: for Phase 0, among other actions, partners are expected to secure necessary equipment and supplies, and develop the knowledge and skills of those expected to implement the plan and procedures; for Phase 1, partners are expected to strictly adhere to best practice recommendations, keep close track of personnel entering the park, identify laboratories to assist with diagnostics, implement quarantine protocols for people arriving from outside the country, and explore tourism suspension policies; in Phase 2, staff access to the parks is to be limited, daily temperature and clinical sign screening implemented, gorilla health monitoring to be continued by veterinary experts, and reporting happening routinely and transparently among the parks; in Phase 3, park entry is to be even more strictly controlled, certain activities halted (e.g., tourism and research), and extensive COVID-19 testing of people and testing of ill gorillas is to be implemented. Further details are included in the contingency plan, which is considered a living document and can be viewed at www.gorillaplan.org.

It is important to note that concurrently with the aforementioned actions, the governments of Rwanda, Uganda and DR Congo were imposing curfews, restrictions on local travel, and shut-downs of various businesses and local transportation to reduce transmission of the virus. While the contingency planning process was underway, all protected area authorities were taking steps to prevent COVID-19 transmission to gorillas. The governments' decision-making processes are beyond the purview of this paper, but suffice it to say that most significantly, tourism was halted by the governments in all mountain gorilla parks by March 25 (and at all great ape sites in Rwanda and Uganda). Numerous workshops and training sessions were led by protected area authorities, in partnership with nongovernmental organizations, to impress upon park personnel the importance of personal hygiene and strict adherence to best practice guidelines for gorilla visitation. PPE (e.g., masks) were procured and distributed. Once tourism was halted, park entry by personnel to continue daily monitoring of gorilla health and safety was paramount: park personnel were instructed to conduct daily fever checks and self-assessments of signs of COVID-19, and as laboratory diagnostic testing capacity ramped up in each country, protected area authorities implemented regular screening of park personnel. For example, in Volcanoes National Park, rangers and trackers were tested for COVID-19 before reporting for rotational duty, and only test-negative individuals were then assigned to 14-day stints at ranger patrol posts, during which movement to and from villages and their homes was not allowed.

Despite best efforts at controlling the outbreak, as has occurred for countries worldwide, COVID-19 has become widespread in all three range countries of the mountain gorilla. By early December 2020, community transmission of COVID-19 was evidenced in most towns and villages adjacent to mountain gorilla parks with a significant number of cases with no known epidemiologic link. For this reason alone, both IGCP and Gorilla Doctors declared themselves to be operating under Phase 3: Response conditions, noting that the presence of the virus in communities adjacent to the protected areas, where park and hospitality personnel lived, was spreading rapidly. They cited the high probability that, despite best intentions and concerted efforts on the part of the protected area authorities to screen park personnel for COVID-19, there was an exceedingly high risk that a COVID-19 positive person would come into close proximity of the gorillas.

4 | OUTCOMES AND LESSONS LEARNED

At the time of writing, the SARS-CoV-2 virus has not been detected in mountain gorillas in the Virunga Massif or Bwindi Impenetrable National Park. Fortunately, few mountain gorillas have exhibited signs of respiratory illness.

That said, the concern for transmission was made all the greater once it was confirmed that SARS-CoV-2 can indeed infect gorillas and cause illness: in early January 2021, San Diego Zoo Wildlife Alliance announced that its western lowland gorilla cohort (eight gorillas) exhibited mild signs of respiratory illness (coughing) and were determined to be COVID-19 positive[1]. This was the first confirmed case of COVID-19 in a great ape, and was widely covered by the press.

COVID-19 contingency planning highlighted the utility of laboratory testing of gorilla samples for COVID-19 screening and diagnosis. Tacit understanding early in the pandemic that existing national reference laboratory facilities and technical expertise for human disease screening and diagnosis could and would be utilized for endangered mountain gorilla testing if necessary soon gave way to the reality that needs for human testing were stretching the capacity of all laboratories, given the imperative for patient diagnoses and pandemic control. The realization that rapid laboratory testing of gorilla samples may not be as available as first thought prompted nonprofit partners to acquire external support for interim testing and purchase of essential laboratory equipment and supplies. Longer term dedicated wildlife laboratory testing capacity is now being pursued in Rwanda by Gorilla Doctors and the Rwanda Development Board.

As well, acknowledging that the Contingency Plan was only relevant in so far as it could be implemented, an external consultant was contracted to critically evaluate the systems and infrastructure in place to respond to COVID-19 in gorillas through key informant

[1]See: https://sandiegozoowildlifealliance.org/pressroom/news-releases/gorilla-troop-san-diego-zoo-safari-park-test-positive-covid-19.

interviews. This review revealed that each country had its unique gaps, for example, in Rwanda there was insufficient access to laboratory testing of nonhuman screening and diagnostic samples; in Uganda, timely testing of human screening and diagnostic samples hindered decisions around park management; in DRC these same gaps were compounded by ongoing insecurity issues in the region. At a regional level, critical gaps in terms of official endorsement by the Protected Area Authorities, policy and institutional alignment at national and regional levels, and information sharing, as well as staffing, PPE supply and restocking plans, and financing, were also identified. Ultimately, recognition of gaps and efforts underway to address them will mean that each site in its respective country is better positioned to conduct laboratory diagnostics and emergency response for wildlife pathogens, and to collaborate effectively at a regional level, in the years to come.

One Health is the perspective that the health of people, animals and the environments they share are intrinsically linked (Zinsstag et al., 2011). In all respects, the COVID-19 pandemic has been a real-world One Health disaster: as early as the declaration of the COVID-19 pandemic, the World Health Organization was assuming that SARS-CoV-2 was an endemic bat virus that spilled over into humans, most likely through contact with an intermediate host commonly handled by people (World Health Organization, 2020). COVID-19 is therefore a One Health "perfect storm": a wild animal virus infected people as the result of human encroachment on wildlife populations and habitat, and spread worldwide to infect nearly 100 million people, causing more than 2.1 million deaths (Johns Hopkins University, January 24, 2021).

While the human suffering and economic devastation caused by the COVID-19 pandemic defies adequate words to describe, it cannot be understated how much the threat posed by the pandemic for threatened and endangered great apes and other primates was of utmost concern. The fact that more than half the world's remaining mountain gorillas are human-habituated and come into close proximity of people every day established the high-risk human-animal interface from Day 1. Furthermore, the fact that great apes, including mountain gorillas, are known to be susceptible to human pathogens further underscored the seriousness of the SARS-CoV-2 threat. In fact, close similarity in the genetic coding for the ACE-2 receptor among humans and primates (Melin et al., 2020) meant that there was even further sound and scientific basis for this concern. Furthermore, the highly protected and managed forests comprising the entirety of the mountain gorilla range are surrounded by the highest density human populations in continental Africa, and therefore the environment itself presented ideal conditions for COVID-19 spread and transmission to the mountain gorillas.

By this same token, One Health became a foundation for response to the threat posed by the COVID-19 pandemic to the conservation of mountain gorillas, in that all elements of prevention and proposed mitigation measures were directed at the human-gorilla interface, and in the context of protected area management. It was a particularly relevant approach, because gorilla tourism brings in much-needed revenue to support park management and protection and gorilla conservation. With global tourism coming to an abrupt halt in March 2020 and gorilla parks closed to all be essential personnel, the drop in revenue was felt acutely: Rwanda suffered $10 million in lost tourism revenue in March and April 2020 alone. Therefore, there was tremendous pressure to plan for the eventual re-opening of the parks to tourism.

Inevitably, people with SARS-CoV-2 infections have been confirmed in communities surrounding the parks, and entry of potentially SARS-CoV-2-infected people into the parks remains a significant risk factor. Nevertheless, Rwanda and Uganda moved forward with reinstating tourism only after taking advantage of the shutdown period to amass critical PPE supplies and develop strict COVID-19 prevention and protection measures for international visitors and gorilla tourists. Gorilla tourism in DRC will re-open shortly, with new protocols in place for park personnel and tourist COVID-19 screening.

The solutions to COVID-19 transmission prevention lay in controlling the immediate and extended environment in which mountain gorillas survive, including minimizing (even halting, then strictly controlling) human-gorilla contact and implementing drastic measures to reduce community transmission. Ultimately, while the concept of One Health could be viewed as the cause for concern, it also became the lens through which COVID-19 prevention measures for mountain gorillas were developed and implemented.

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AUTHOR CONTRIBUTIONS

Kirsten Gilardi: conceptualization (equal); data curation (equal); formal analysis (equal); funding acquisition (equal); investigation (equal); methodology (equal); project administration (equal); resources (equal); supervision (equal); validation (equal); visualization (equal); writing original draft (lead); writing review and editing (lead). **Julius Nziza**: conceptualization (supporting); formal analysis (supporting); investigation (supporting); methodology (supporting); validation (equal); writing review and editing (supporting). **Eddy Kambale Syaluha**: conceptualization (supporting); formal analysis

(supporting); investigation (supporting); methodology (supporting); validation (equal); writing review and editing (supporting). **Richard Muvunyi**: conceptualization (supporting); formal analysis (supporting); investigation (supporting); methodology (supporting); validation (equal); writing review and editing (supporting). **Robert Aruho**: conceptualization (supporting); formal analysis (supporting); investigation (supporting); methodology (supporting); validation (equal); writing review and editing (supporting). **Chantal Shalukoma**: conceptualization (supporting); formal analysis (supporting); investigation (supporting); methodology (supporting); validation (equal); writing review and editing (supporting). **Andrew Seguya**: conceptualization (supporting); formal analysis (supporting); investigation (supporting); methodology (supporting); validation (equal); writing review and editing (supporting). **Anna Behm Masozera**: conceptualization (lead); formal analysis (equal); funding acquisition (lead); investigation (equal); methodology (equal); project administration (lead); resources (lead); validation (equal); writing original draft (equal); writing review and editing (supporting).

PEER REVIEW

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ORCID

Kirsten Gilardi https://orcid.org/0000-0002-6088-2178

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