





INTRODUCTION

Section 1: Disease, Health and Ape Conservation

The State of the Apes Series¹

Commissioned by the Arcus Foundation, the *State of the Apes* series aims to raise awareness about the status of apes around the world and the impacts of human activities on apes and ape habitat. Apes are closely related to humans and they – and their habitats – are vulnerable to many anthropogenic threats. To build an understanding of both the severity and extent of these threats, as well as potential means for preventing and mitigating them, the volumes in this series feature original research and analysis, case studies and best practice from leading scholars and practitioners active in various sectors, including conservation, industry and academia.

This Arcus Foundation initiative is designed to inform debate, practice and policy in ways that reconcile ape conservation and welfare with socioeconomic development. Robust statistics on the status and welfare of apes are derived from the Ape Populations, Environments and Surveys (A.P.E.S.) database, available at iucngreatapes.org/apes-database.

This volume—the final one in the *State of the Apes* book series—examines ape conservation and welfare through the lens of disease and health. It explores factors such as the ethics of intervening in and managing ape health; the impact of research and tourism activities on apes; the One Health approach; and disaster management and the protection of apes. It shows how the welfare of apes is interrelated with that of the people who share their habitats, while also demonstrating the benefits of integrating ape conservation in health, social and economic development (including sectors such as extractive industries, industrial agriculture, infrastructure development) and regulatory policy and practice at all levels, from the local to the international. Moreover, the analysis and findings presented throughout the chapters are intended to help conservation specialists enhance their own practice.

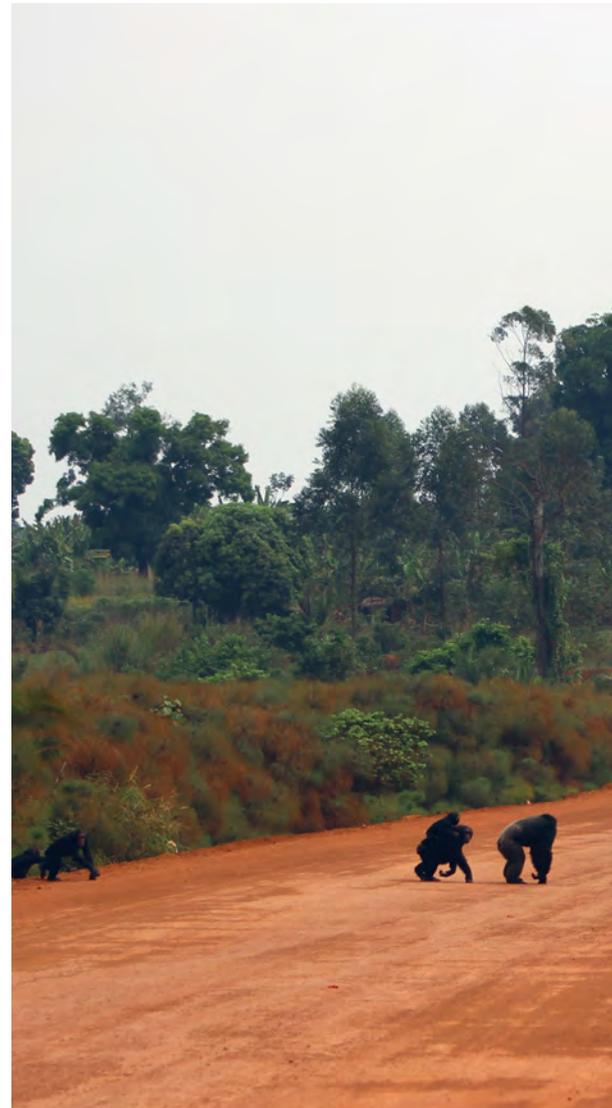
The volume's focus is on all non-human ape species: bonobos, chimpanzees, gorillas, orangutans and gibbons. The analysis concentrates on apes in range countries, which encompass much of the tropical belt of Africa and Southeast Asia, although it also reviews the welfare of captive apes in facilities worldwide. To ensure a holistic overview of current thinking and practice regarding health and disease in relation to ape survival and welfare, the Arcus Foundation commissioned contributions from a range of experts working in academia, conservation, the private sector, sanctuaries, health and veterinary medicine.

Disease, Health and Ape Conservation

The World Health Organization defines health as a “state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity” (WHO, 2020a). While the determinants of health are

complex and interconnected for every individual species, comparisons of health needs are possible across taxa that are anatomically and physiologically similar, such as humans and apes. Species with close genetic relationships are susceptible to many of the same infectious and non-infectious diseases, and disease-causing organisms (pathogens) can move between them.

Managing the spread of disease within or between individuals, groups and species requires an understanding of the nature



of the disease, its ability to spread and its potential impacts. The COVID-19 pandemic has demonstrated the challenges of managing disease spread and impact at the global scale, including at the political, social and structural levels.

As the Anthropocene unfolds, the impact of humanity on all ecosystems on the planet is becoming more visible and better understood. Climate and ecological systems are collapsing and one million species are threatened with extinction (IPBES, 2019;

IPCC, 2023). Ecosystems are struggling to cope with continued and cumulative stresses. All the while, deforestation, encroachment into natural habitat and other human activities are driving an increase in the frequency of interactions between people and various forms of wildlife, including viruses, parasites, bacteria and fungi (Nellemann and Newton, 2002). The consequence is a heightened risk of disease transmission, with serious implications for conservation, biodiversity protection and human health (Balasubramaniam

Photo: Historically, wild apes have shared their natural environment with various wildlife species and their associated pathogens, but had limited contact with humans until the current age. Now, many wild apes live in habitats that are subject to different degrees of anthropogenic encroachment. Chimpanzees crossing a road in Bulindi, Uganda.
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Photo: Sanctuaries and zoos face similar health threats, such as human diseases and geriatric disorders; however, spillover of wildlife pathogens can and does occur.
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Lincoln Park Zoo

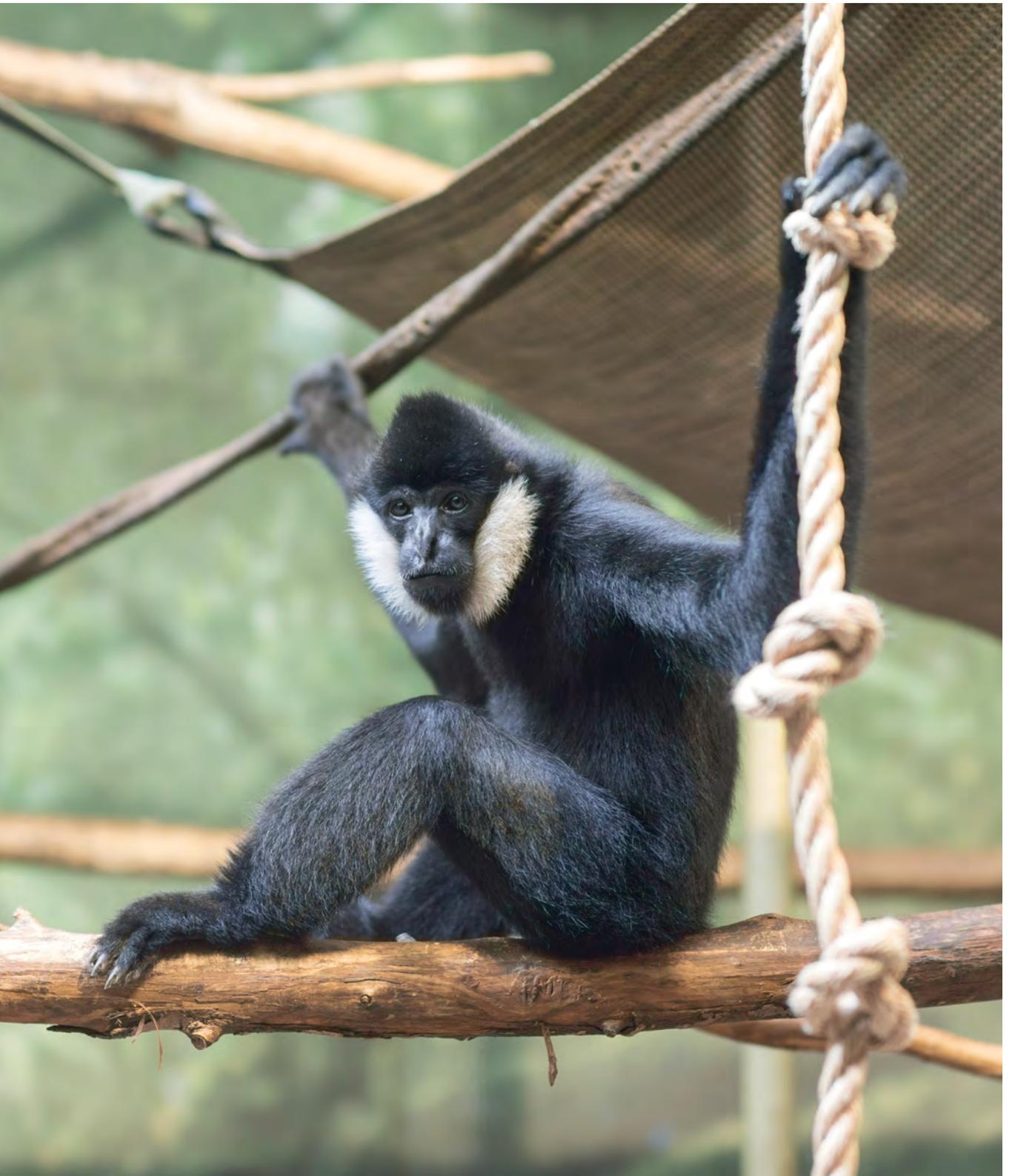
et al., 2022; Conover and Conover, 2022; Marrana, 2022; Muehlenbein, 2013).

Like humans, many apes are social beings who live in groups and interact closely with each other. The health of any group is closely tied to the health of individuals within that group, as well as to the size of the group. The smaller a population, the more vulnerable it is to disease (Prado-Martinez *et al.*, 2013). Moreover, species-specific behaviors and social systems can influence the risk and the impact of diseases. The settings in which apes live—be they natural forested habitat, sanctuaries or rehabilitation centers in their range countries, or zoos and sanctuaries elsewhere in the world—also come with unique sets of health-related risks and challenges (see Annex II for a summary table of ape health and disease issues).

Viewed through a conservation lens, disease represents a major threat to the survival of apes and other species that are threatened with extinction (Gilardi *et al.*, 2015). Indeed, infectious disease is often listed among the principal threats to ape conservation, along with habitat loss and hunting, which can also expose apes to health threats. The burning of habitats, for example, can pose non-infectious health risks, while the degradation of landscapes can change species composition and behavior, potentially altering primates' exposure to infectious agents (Erb *et al.*, 2018; Herrera and Nunn, 2019). Similarly, encroachment of hunters into wildlife habitats heightens not only the threat that apes may be injured or killed, but also the likelihood of exposure to human pathogens, to which apes can be highly susceptible (Köndgen *et al.*, 2008; Laurance *et al.*, 2006; see Figure 1.2). Diseases that can be transmitted from animals to humans and from humans to animals are called “zoonoses” (Hubálek, 2003).

Historically, wild apes have shared their natural environment with various wildlife species and their associated pathogens, yet





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they probably had limited contact with humans until the current age. Nowadays, many wild apes live in habitats that are subject to different degrees of anthropogenic encroachment; in fact, more than 70% of wild ape populations are found outside protected areas (see Chapter 7). Within national parks or similarly protected areas, contact with humans can be relatively controlled, such as when people are involved in research, tourism or park protection and hunting. Outside of national parks, apes sometimes inhabit forests that are heavily used by humans, be it for hunting, fishing or the harvesting of other forest resources. Apes also enter human habitats, for example to forage crops. Under these circumstances, the likelihood of pathogen transmission rises, and apes are more likely to sustain human-caused injuries, including from snares.

In zoos, apes live in artificial conditions and in close contact with people, which can significantly increase the likelihood of infection with human pathogens (see Figure 1.2). Strategies to mitigate this risk include the use of masks, gloves and other personal protective equipment, as well as disinfectant footbaths (Kalter, 1989). While the spillover of pathogens between zoo animals may be limited, captive apes can come into contact with rodents and pathogens from other enclosures or if they are kept in mixed-species enclosures (Hardgrove *et al.*, 2021). Confinement in enclosures and associated stress can increase the burden of certain ape-specific pathogens, such as gastrointestinal parasites (Toft, 1986). Many of the captive apes in sanctuaries, particularly in the United States, have come from laboratories where they were deliberately infected with various pathogens for research (Knight, 2008; Morimura, Idani and Matsuzawa, 2011). Non-infectious diseases are also common in captivity. Some are the direct result of stress, diet or other factors linked to captivity, while ape geriatric

diseases are linked to relatively long lifespans, which are rarely observed in the wild (Lowenstine, McManamon and Terio, 2016).

Apes in range country sanctuaries and rehabilitation centers occupy an intermediate position between captive and wild apes, although this volume generally groups them together with captive populations. Most of these “semi-captive” animals were born in the wild, and some are eventually released back into the wild, which comes with the risk of pathogen carryover to wild individuals and groups (Köndgen *et al.*, 2017; Sherman *et al.*, 2021). Sanctuaries and zoos face similar health threats, such as human diseases and geriatric disorders; however, spillover of wildlife pathogens can and does occur, as evidenced by the transmission of the monkeypox virus to sanctuaries (see Figure 1.2 and Chapters 1, 7 and 8).

Regardless of the setting, apes encounter myriad (micro)organisms that can impact their health in various ways. These include bacteria, viruses, viruses of bacteria, fungi, protozoa and a variety of macroparasites (Gogarten *et al.*, 2018, 2021; Nishida and Ochman, 2019). Those that cause visible signs of disease were historically the most studied, but they are vastly outnumbered by commensal (micro)organisms. Scientists have characterized only a fraction of the latter and have examined an even smaller proportion with respect to their effects on ape hosts (Bueno de Mesquita *et al.*, 2021; Gogarten *et al.*, 2021).

With the advent of next-generation sequencing technologies, the human gut microbiome received intense research interest. Studies suggest that this gut ecosystem has various impacts on health, including in terms of digestion, immunity and psychological wellbeing (Hooper, Littman and Macpherson, 2012; Tremaroli and Bäckhed, 2012; Winter *et al.*, 2018). Yet, even for humans, the understanding of how the microbiome interacts with host health is

rudimentary and often relies on extrapolation from experimentation with model organisms (iHMP Research Network Consortium, 2019). While it seems likely that the gut microbiome of apes has a comparable importance for their health and wellbeing, associated research is still in its infancy (Björk *et al.*, 2019). Similarly, researchers have documented clinical signs of gastrointestinal parasites in captive apes, yet their impact on wild ape health remains largely unknown (Gogarten *et al.*, 2020).

This volume of *State of the Apes* examines what steps can be taken to mitigate disease risks to apes, improve the resilience of their populations and restore their role in ecosystem function. While highlighting the continuum between welfare and conservation, it reviews how human-caused changes to ape habitats, food availability, sociality and behavior, along with proximity to people, affect ape health and wellbeing.

The volume identifies pathogens, yet it places more emphasis on the diseases they cause. For example, Chapter 1 mentions that severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causes COVID-19, but the book focuses more generally on the health impacts of the disease and options for mitigating transmission risks. COVID-19 is referenced frequently throughout the volume, not only in view of the far-reaching consequences of the pandemic, but also because associated concepts and guidance apply to all infectious diseases. The COVID-19 pandemic, caused by SARS-CoV-2, has lent a sense of urgency to much of this research and debate.

Thematic Chapters

The thematic section of this edition of *State of the Apes* comprises six chapters, which are briefly described below. The introduction to Section 2 presents Chapters 7 and 8.

Chapter 1 provides an overview of the factors that impact the health of wild and captive apes, providing evidence of known pathogens and highlighting the areas that require greater research and investigation.

Chapter 2 contextualizes the health of an individual within that of the population and the larger ecosystem, linking human, animal and environmental health. It presents the One Health approach as a way of considering the interconnections between humans, domestic animals and wildlife and the social and ecological environments that they share. The chapter provides a series of case studies that demonstrate how disease can be prevented through system-level approaches.

Chapter 3 examines two areas of human activity that can have a particular impact on ape health: tourism and research. Both of these activities bring humans in close and repeated contact with apes. Tourists and researchers who come from different geographical regions are especially likely to increase apes' risk of naive contacts with pathogens. These activities can significantly increase the likelihood and potential severity of health consequences for apes, whether in captivity or in free-ranging settings. The chapter examines the potential for disease spillover in both directions—from apes to humans and vice versa.

Chapter 4 considers the main strategies for managing ape health and the linkages with public health. The authors review decision-making processes designed to help veterinarians assess potential limitations and benefits of proceeding with health interventions.

Chapter 5 explores some of the ethical considerations that are relevant to ape health care and protection, including in regions of the world where medical services are often severely limited for human populations. In examining challenges inherent in balancing the value of the individual against that of the population, the chapter points to

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compassionate conservation as a method for resolving such tensions. These concepts are complex and context-specific and have value in raising awareness about the need for explicit consideration of the ethics of ape protection and care.

Chapter 6 analyzes disease outbreaks and other health-related crises from the perspective of disaster management. It covers risk mapping, risk mitigation and capacity in disaster management, prevention, preparedness, response and recovery.

Acknowledgments

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Endnotes

- 1 Adapted from the Introduction to the first volume, *State of the Apes: Extractive Industries and Ape Conservation* (Arcus Foundation, 2014, pp. 2–5).
- 2 Arcus Foundation (www.arcusfoundation.org).
- 3 Arcus Foundation (www.arcusfoundation.org).
- 4 Arcus Foundation (www.arcusfoundation.org).
- 5 Helmholtz Institute for One Health, Helmholtz-Centre for Infectious Research (www.helmholtz-hzi.de/en) and Robert Koch Institute (www.rki.de).
- 6 Helmholtz Institute for One Health, Helmholtz-Centre for Infectious Research (www.helmholtz-hzi.de/en) and Robert Koch Institute (www.rki.de).
- 7 Helmholtz Institute for One Health, Helmholtz-Centre for Infectious Research (www.helmholtz-hzi.de/en), Robert Koch Institute (www.rki.de) and University of Greifswald (zoologie.uni-greifswald.de/en/organization/departments/applied-zoology-and-nature-conservation).
- 8 Helmholtz Institute for One Health, Helmholtz-Centre for Infectious Research (www.helmholtz-hzi.de/en) and Robert Koch Institute (www.rki.de).
- 9 Helmholtz Institute for One Health, Helmholtz-Centre for Infectious Research (www.helmholtz-hzi.de/en) and Robert Koch Institute (www.rki.de).
- 10 At the time of writing: International Animal Rescue (www.internationalanimalrescue.org).

SECTION 1

