Photo: One Health principles and approaches have a clear role to play in multiple facets of ape health, welfare and conservation. © Christophe Courteau / naturepl.com

CHAPTER 2

The Role of One Health at the Human–Ape Interface

Introduction

In the context of multiple interconnected social and environmental crises, addressing health-related threats requires integrated approaches that consider the interconnections among humans, companion animals, livestock and wildlife and their respective social and ecological environments (Zhu *et al.*, 2020; Zinsstag *et al.*, 2011). One Health is a systems-based, transdisciplinary approach to creating and implementing health-based solutions in the face of such complexity.

The definition and implementation of the One Health approach has matured over the past two decades (Capua and Cattoli, 2018; Gibbs, 2014; Lainé and Morand, 2020; see Boxes 2.1 and 2.2). Early efforts recognized the importance of sustainable, healthy,

nature–human coupled systems and focused on the need for an expanded conceptual approach to the interconnected health and wellbeing of humans, animals and their environment. During the subsequent period, many groups concurrently defined principles, methods and the practice of One Health. The most recent approach, which is still in its infancy, places the focus on design thinking, which includes measuring and evaluating programmatic impacts.

This chapter provides an overview of the history and core principles of One Health and explores its role in ape conservation, in the context of the challenges of environmental degradation and biodiversity loss. To highlight the diverse applications of One Health in supporting ape conservation, it presents case studies on various themes: community health, ecosystem health methods, capacity building, land use, internal health, translational medicine and ecosystem conservation.

Key findings include:

- The complex challenges of improving ape conservation must be contextualized

BOX 2.1

What Is One Health?

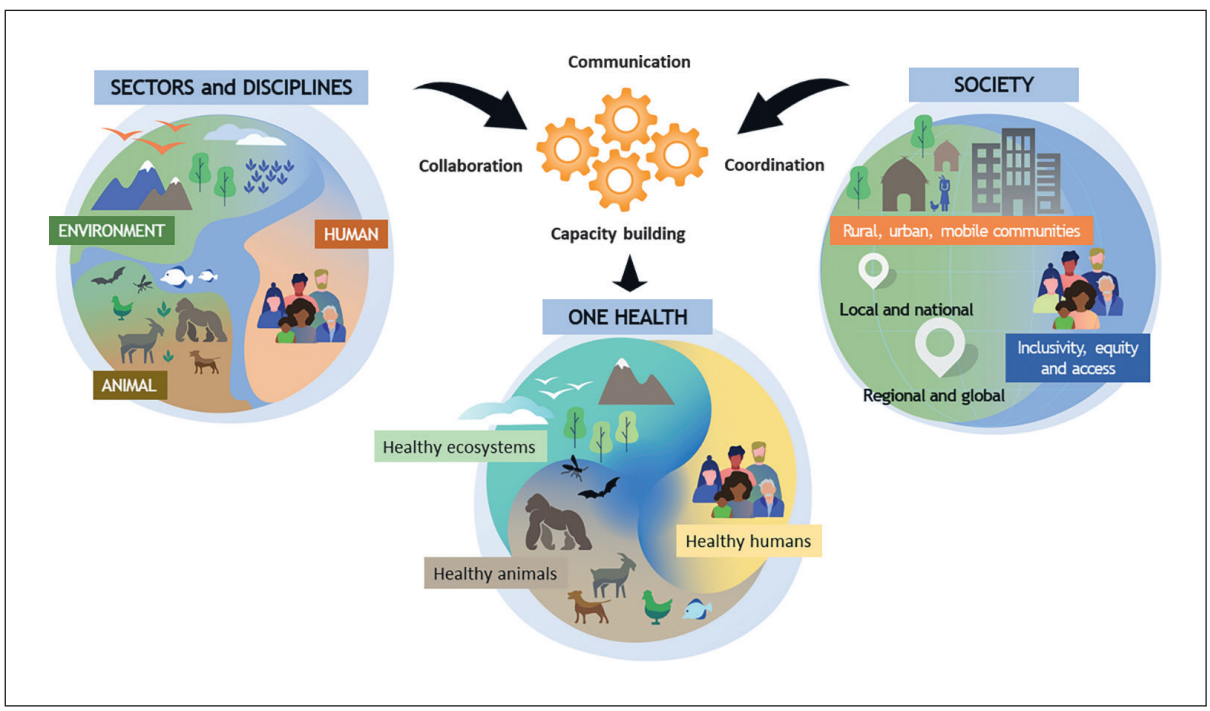
The One Health paradigm is:

> a collaborative, multisectoral, and transdisciplinary approach—working at local, regional, national, and global levels—with the goal of achieving optimal health outcomes recognizing the interconnections between people, animals, plants, and their shared environment (CDC, n.d.-b).

The approach reflects the complex, interconnected environmental systems that make up the planet, while also providing an effective means of solving individual, population, species and ecosystem health issues holistically. While One Health has been represented in multiple fashions over the years, this chapter adopts the view of the One Health High-Level Expert Panel to illustrate the paradigm's most up-to-date collaborative nature (see Figure 2.1).

FIGURE 2.1

Representation of One Health



Source: OHHLEP *et al*. (2022), reproduced under the Creative Commons Attribution License

within global sustainability goals. One Health is a mechanism for success here.

- The One Health approach to solving health issues converges with those of related fields, including ecosystem health, conservation medicine and planetary health.
- One Health principles and approaches have a clear role to play in multiple facets of ape health, welfare and conservation (Grützmacher *et al.*, 2021), as evidenced by an expanding set of case studies in areas as diverse as ecology, disaster preparedness, public health, community development, tertiary education, veterinary science, microbiology, science communication, land tenure and environmental law, and resource management.

Ape Conservation, One Health and Sustainable Development

The world changed with the advent of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which caused the COVID-19 pandemic (Guo *et al.*, 2020). No longer can the pieces of the global biosocial system be viewed as disconnected. That recognition can help to support the United Nations (UN) 2030 Agenda for Sustainable Development, which provides a shared blueprint for meeting human needs while protecting the planet. Adopted by all UN member states in 2015, the Agenda's 17 Sustainable Development Goals (SDGs) "recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth—all while tackling climate change and working to preserve our oceans and forests" (UN DESA, n.d.). Ape conservation intersects with almost every SDG.

Indeed, the conservation and sustainability agendas dovetail with respect to biodiversity protection, climate effects on habitat, migration, health and sustainable natural resource management. The SDGs with the most direct links to the conservation agenda are Goal 13 on climate change, Goal 15 regarding life on land and Goal 16, which focuses on peace, justice and strong institutions. More indirect connections to conservation are evident with respect to poverty and hunger reduction (Goals 1 and 2) and responsible consumption (Goal 12), which relates to human demand for ecosystem services and the trade in wildlife and their products, in the context of supporting economic and nutritional stability.

Overall, growing human contact with apes has negatively affected the "good health and well-being" (Goal 3) of all ape species and humans, particularly through infectious disease "spillover" events and their "spillback" from animal care staff to captive apes. Increased contact does not necessarily result in exclusively negative health impacts, however. While ecotourism can threaten apes' wellbeing by raising their stress levels, for example, it can also positively influence people's mental health and support ape welfare, such as by enhancing protection from hunting or securing revenue for conservation (see Chapter 3).

Education and gender equality (Goals 4 and 5), both of which link to human health, are increasingly part of conservation discussions, especially in relation to tropical areas with suitable ape habitat. On the whole, investments in community capacity and capability in such areas are sorely needed (Razanatsoa *et al.*, 2021; Unwin *et al.*, 2022).

The convergence of ape conservation and sustainability targets has also been promoted at the highest political levels. In 2006, in his keynote address to the International Primatological Society in Entebbe, Uganda, President Yoweri Museveni made a compelling

Photo: Addressing health-related threats requires integrated approaches that consider the interconnections among humans, companion animals, livestock and wildlife and their respective social and ecological environments. © Justin Mott / Kindred Guardians Project / We Animals Media

argument for the shared agendas of ape conservation and sustainable development in his country. He highlighted clean water and sanitation (Goal 6), affordable energy (Goal 7), economic growth (Goal 8), innovation and infrastructure (Goal 9) and reduced inequality (Goal 10) as key to sustainability for both apes and humans in Uganda.[1]

While some progress has been made in efforts to achieve both the SDGs and ape conservation goals, increasing contact between humans and apes is ushering in new challenges that call for innovative approaches (Travis, Lonsdorf and Gillespie, 2018). The One Health model provides a foundation for much-needed win–win solutions.

A Short History and Core Principles of One Health

The past two decades have seen milestones in the development of the One Health model. In 2004, the Wildlife Conservation Society and Rockefeller University hosted the "One World, One Health" symposium, which focused on the movement of infectious diseases among humans, domestic animals and wildlife populations. The output, entitled "Manhattan Principles," listed 12 recommendations for establishing a more holistic approach to preventing cross-species infectious disease transmission while maintaining ecosystem integrity and the benefits it bestows on humans and animals (Karesh and Cook, 2009).

In 2009, following growing acceptance and application of this paradigm, the One Health Commission was created to foster consensus—or at least convergence—among practitioners around the globe. In 2019, the Manhattan Principles were updated in Berlin to reframe the unifying approach to human, animal and ecosystem health in an economic and sociopolitical context (WCS, n.d.-a; see Box 2.2). Two years later, in 2021,

the One Health High-Level Expert Panel was created as an advisory body to the Commission's key supporting agencies, the World Health Organization (WHO), the Food and Agriculture Organization (FAO) and the World Organisation for Animal Health (founded as OIE), which were joined by the UN Environment Programme in 2022. Defining One Health was among the Panel's first duties (see Box 2.1).

In both its scope and its approach, One Health intersects—and converges—with several related disciplines and paradigms, including ecosystem health, conservation medicine and planetary health (Lerner and Berg, 2017; Wallace *et al.*, 2015; Wilcox *et al.*, 2019; Xie *et al.*, 2017). All these fields can contribute towards achieving the SDGs. Errecaborde *et al.* (2019) summarize their similarities and differences, while Roger *et al.* (2016) draw out their complementary natures, highlighting that all these paradigms:

- are motivated by the conviction that health concerns must be addressed at the human–animal interface within their broader natural and social environments;
- seek to integrate scientific disciplines through multi- and cross-disciplinary approaches;

BOX 2.2

Berlin Principles of One Health

The 2019 Berlin Principles, presented in their entirety below, are aimed at overcoming systemic policy and social challenges to enable a holistic, global approach to addressing growing health threats.

We urge world leaders, governments, civil society, the global health and conservation communities, academia and scientific institutions, business, finance leaders, and investment holders to:

1) Recognize and take action to retain the essential health links between humans, wildlife, domesticated animals and plants, and all nature; and ensure the conservation and protection of biodiversity which, interwoven with intact and functional ecosystems, provides the critical foundational infrastructure of life, health, and wellbeing on our planet;
2) Take action to develop strong institutions that integrate understanding of human and animal health with the health of the environment, and invest in the translation of robust science-based knowledge into policy and practice;
3) Take action to combat the current climate crisis, which is creating new severe threats to human, animal, and environmental health, and exacerbating existing challenges;
4) Recognize that decisions regarding the use of land, air, sea, and freshwater directly impact health and wellbeing of humans, animals, and ecosystems and that alterations in ecosystems paired with decreased resilience generate shifts in communicable and non-communicable disease emergence, exacerbation and spread; and take action to eliminate or mitigate these impacts;
5) Devise adaptive, holistic, and forward-looking approaches to the detection, prevention, monitoring, control, and mitigation of emerging/resurging diseases and exacerbating communicable and non-communicable diseases, that incorporate the complex interconnections among species, ecosystems, and human society, while accounting fully for harmful economic drivers, and perverse subsidies;
6) Take action to meaningfully integrate biodiversity conservation perspectives and human health and wellbeing when developing solutions for communicable and non-communicable disease threats;
7) Increase cross-sectoral investment in the global human, livestock, wildlife, plant, and ecosystem health infrastructure and international funding mechanisms for the protection of ecosystems, commensurate with the serious nature of emerging/resurging and exacerbating communicable and non-communicable disease threats to life on our planet;
8) Enhance capacity for cross-sectoral and trans-disciplinary health surveillance and clear, timely information-sharing to improve coordination of responses among governments and non-governmental organizations, health, academia and other institutions, the private sector and other stakeholders;
9) Form participatory, collaborative relationships among governments, NGOs, Indigenous Peoples, and local communities while strengthening the public sector to meet the challenges of global health and biodiversity conservation;
10) Invest in educating and raising awareness for global citizenship and holistic planetary health approaches among children and adults in schools, communities, and universities while also influencing policy processes to increase recognition that human health ultimately depends on ecosystem integrity and a healthy planet.

Source: Grützmacher *et al*. (2021, p. 3), reproduced under the Creative Commons Attribution License

- aim to mitigate the risks threatening ecosystems and public health, including veterinary public health;
- address the complexity of diseases and health; and
- struggle to define their boundaries despite their apparent similarities regarding principles and objectives.

Globalization of the Principles of One Health

While the term One Health is the product of a long history of philosophical discussion, the focus of more recent deliberations has been on advancing theories and methods in support of implementation strategies (Mackenzie and Jeggo, 2019; World Bank, 2021). Today, One Health is globally recognized as a theory of change underpinning a renewed focus on systemic approaches to complex problems; however, the conditions under which they should be employed, the modalities for their implementation, and evaluation processes and metrics are still being designed and tested.

As it continues to gain momentum, One Health is serving as a roadmap for connecting collaborative science to policymaking in the context of several international health-related efforts, including:

- the Global Health Security Agenda, a partnership of more than 50 countries, international organizations and non-governmental stakeholders focused on

Photo: One of the 2019 Berlin Principles for One Health is to take action to combat the current climate crisis, which is creating new severe threats to human, animal and environmental health, and exacerbating existing challenges.
© SOCP

combating infectious diseases (Center for Global Health, 2016);

- the WHO–FAO–OIE agreement to combat zoonotic diseases and antimicrobial resistance (Lee and Brumme, 2013; WHO, FAO and OIE, 2019);
- the US Agency for International Development's Emerging Pandemic Threats Program (USAID, n.d.); and
- the global COVID response (Ruckert *et al.*, 2020).

Recognizing the need for more tangible and implementable processes to support this widespread acceptance, in 2018 the EcoHealth Alliance and the World Bank published the *Operational Framework for Strengthening Human, Animal, and Environmental Public Health Systems at Their Interface*. The framework updates the previous operational definition of One Health, which had been in use during the response to the avian and pandemic influenzas in 2005–2014. Specifically, it expands the description of One Health as "a framework for enhanced collaboration in areas of common interests (intersections), with initial concentration on zoonotic diseases, that will reduce risk, improve public health globally and support poverty alleviation and economic growth in developing countries" to include "the discrete disciplinary involvement of human health, animal health, and environmental health, and focus on those infectious disease-related issues (including antimicrobial resistance) that undermine overall health and well-being" (World Bank Group, 2018, p. 3). The intent is to improve health in all the above dimensions, address drivers of processes that threaten health and optimize the effectiveness of systems to achieve these goals.

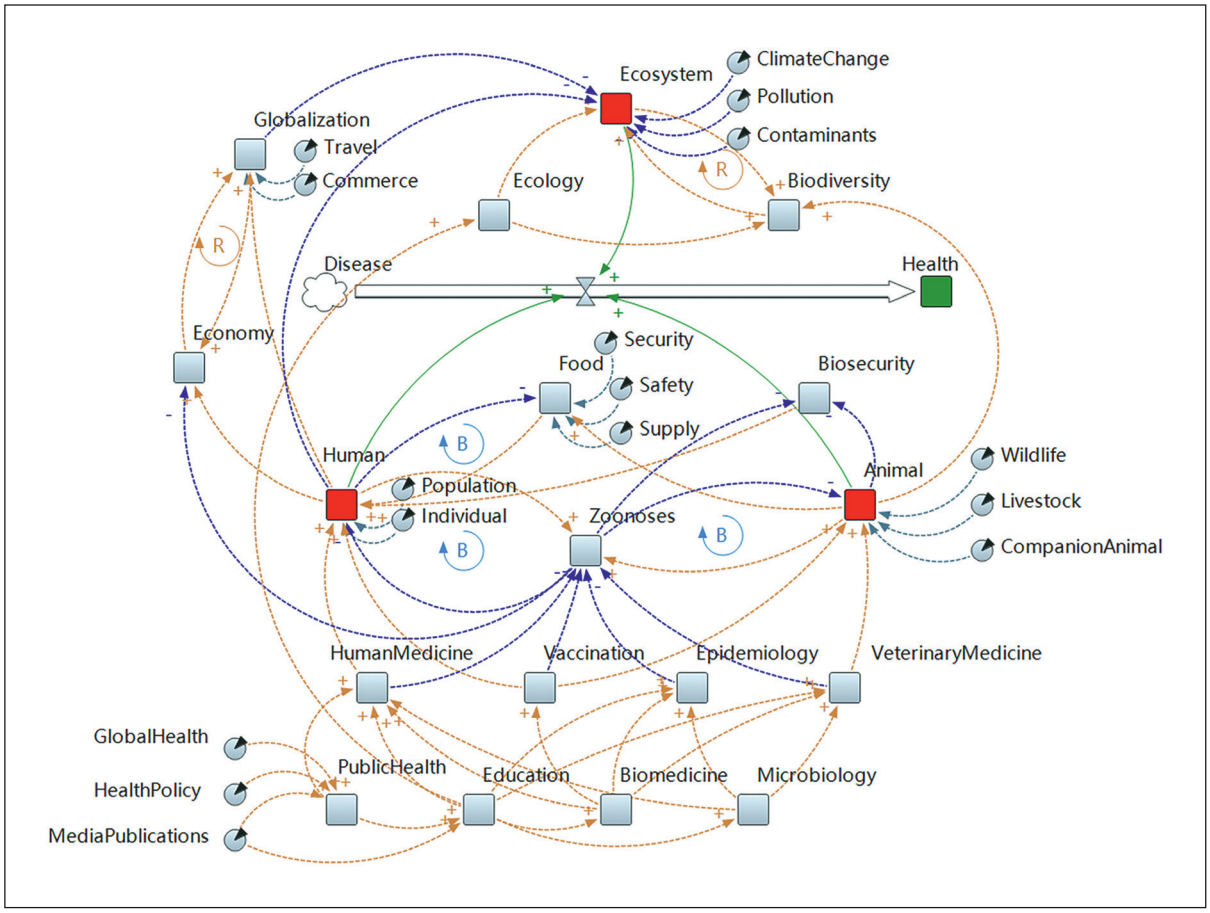
Evaluations of the One Health framework have led to the development of dedicated monitoring systems. In 2014, a qualitative assessment concluded that "there is no shared conception of health across disciplines and One Health suffers from a lack of strong environmental stakeholders" (Stephen and Karesh, 2014). Subsequent studies of One Health in practice, which found that it lacked a standardized framework and evaluation metrics, called for greater proof of concept and standard indicators (Baum *et al.*, 2017; Häsler *et al.*, 2014). In response to such criticism, the European Union in 2014 supported the Network for the Evaluation of One Health working group, which established, tested and published an open-source text on a comprehensive monitoring and evaluation protocol for One Health (Rüegg, Häsler and Zinsstag, 2018). These tools and indicators have since been incorporated into a One Health package under the Global Health Security Agenda (CDC, n.d.-a; Center for Global Health, 2016; Fasina *et al.*, 2021; Kelly *et al.*, 2020; Rabinowitz *et al.*, 2018).

To produce a comprehensive systems model of One Health, Xie *et al.* (2017) conducted a systematic literature review of 577 One Health articles. Based on the findings, they developed the "One Health Cosmos," which illustrates the fundamental roles of ecology and social aspects such as economy and commerce in the management of health issues at a biosocial system level (see Figure 2.2).

The One Health model was designed by health professionals working at the wildlife–human–livestock interface. It has since been applied in differing contexts the world over and has become an accepted—if not yet standardized—way to approach various complex problems, including human and animal welfare and wellbeing, environmental and ecotoxicological concerns, agricultural (plant or animal) sustainability issues, and challenges related to the aquatic environment. Nevertheless, conservation efforts remain largely focused on infectious disease and translational and

FIGURE 2.2

The One Health Cosmos



Notes: As specified by Xie *et al*. (2017): "One Health Cosmos shows the relationships between the various disciplines and complex problem descriptors that are reported to fall within the One Health concept. Squares and circles represent nodes, and the arrows connecting nodes represent causal links. Brown color is used to show positive causal link which also includes a '+' sign beside each arrowhead. Negative causal link is portrayed with a blue color and '-' sign beside each arrowhead. A positive causal link means that both the causative and the resultant factors increase or decrease in the same direction. A negative causal link indicates that the two linked factors change in opposite directions. The positive reinforcing loop has a 'R' in the clockwise cycle. A negative reinforcing loop opposite has a 'B' in the counter-clockwise cycle. A big arrow shows the direction of this relationship between disease and health through One Health."

Source: Xie *et al*. (2017, fig. 2), reproduced under the Creative Commons Attribution License

comparative medicine, perhaps reflecting the dearth of guidance on employing the One Health approach in real-world settings. The World Bank's abovementioned *Operational Framework* begins to fill this gap by providing detailed guidance on multiple aspects of the model. Box 2.3 presents basic steps and questions that can guide any group in developing a One Health project or consortium (Waltner-Toews, Kay and Lister, 2008).

One Health and the Human–Ape Interface

Complex problems often require multifocal solutions and teamwork. One Health supports the inclusion of all relevant stakeholders in solution-based processes, using the theory that inclusion leads to more robust, implementable and sustainable solutions, both in-situ and ex-situ (Xie, 2021).

BOX 2.3

How to Develop a One Health Project

The following steps and questions are designed to assist groups in establishing a One Health project or consortium.

1. **Problem formulation**. Why is a potential One Health approach needed or useful? Discuss which systems are involved and how they interact. Do they involve complex issues that involve the human–animal–environmental interface and that cannot be solved using traditional methods and approaches?
2. **Stakeholders**. What stakeholders are involved or likely to be affected? One Health approaches are suited to problems that require engagement from multiple stakeholders, potentially with differing agendas or preferred outcomes. Identify principal stakeholders, their conflicts of interest and related power dynamics.
3. **Problem mapping**. Map out the problem, including all interconnecting systems. Highlight the intersections and how they influence each other. Think about the historical development of systems: what has stabilized or destabilized them?
4. **Access to information**. Identify critical barriers to a better understanding of the problem, assess what information is available and determine what further information is needed to understand or address the problem.
5. **Solutions**. Explore whether and how potential solutions can be made acceptable, affordable, sustainable and equitable for all stakeholders.

Source: Waltner-Toews, Kay and Lister (2008)

The model also allows for an assessment of the role socioeconomic factors play in decisions and behavior that increase health risks, including disease emergence (Dobson *et al.*, 2020; Wallace *et al.*, 2015). The likelihood of such risks has grown during the current geological epoch—commonly termed the Anthropocene—as human values, choices and activities have increasingly driven both physical and biological global processes (Crutzen, 2006). An estimated 75% of the planet's terrestrial landscapes is currently human-modified (Venter *et al.*, 2016). As highlighted in other volumes of *State of the Apes*, agricultural intensification (of crops and livestock) is the dominant form of human-driven landscape modification. Often undercutting the resilience and sustainability of natural systems, the process has resulted in increased contact between humans, livestock and wildlife, including apes (Arcus Foundation, 2015; IPBES, 2020; UNEP and ILRI, 2020; Williams *et al.*, 2021). This increased interaction is associated with an estimated 25% of all infectious disease emergence and 50% of all zoonotic disease emergence (Rohr *et al.*, 2019).

Efforts to minimize health risks associated with the interface between humans and captive apes can also benefit from the One Health approach, particularly as it interacts with the fields of animal welfare science and translational medicine research (Pinillos *et al.*, 2016; see Chapter 8). The model is applicable in all captive situations, no matter whether apes are kept as pets, for exhibition or educational purposes, as part of a conservation program or for research. An example of One Health under the One Welfare paradigm is the design and validation of the Enclosure Design Tool, which allows caregivers to compare captive apes' behaviors to those in the wild and to adjust welfare plans accordingly (see Case Study 8.1).

Apes, Humans and Infectious Disease

As evidenced by the COVID-19 pandemic, human health and the environment are intimately intertwined. Although it is well established that human disturbance of ecosystems can create disease-related threats for apes and other endangered species, predicting the direction, magnitude and mechanisms of disease emergence remains a challenge (Gillespie and Chapman, 2006; Gillespie, Chapman and Greiner, 2005). For instance, wild mammals are frequently the primary source of novel pathogens found in humans, but making related predictions and assessing risk remain difficult due to the lack of basic presence and absence data for zoonotic viruses for almost 90% of wild mammal species that could serve as reservoirs (Calvignac-Spencer *et al.*, 2012; Johnson *et*

al., 2020; Zhu *et al.*, 2020). This example highlights the desperate need for well-designed empirical studies that integrate animal and human pathogen surveillance as well as robust ecological data on natural and anthropogenic systems, as a detailed understanding of population and community dynamics is central to solving these problems (Gillespie, Nunn and Leendertz, 2008; Lonsdorf *et al.*, 2022).

The risk of disease spillover is directly related to human behaviors, including values and choices. In fact, evidence suggests it is most strongly associated with agricultural-driven decisions such as tropical forest conversion to monoculture plantations and industrial livestock production (Rohr *et al.*, 2019). This association reflects three key factors, namely that pathogen diversity correlates with host diversity; that the highest host diversity occurs in tropical forests; and that commercial agriculture is expanding rapidly in tropical forest regions (Gillespie *et al.*, 2021). Forest conversion increases the risk of pathogen spillover in two ways. First, it increases the interface between wild mammals and people—and thus the number of interactions that facilitate disease transmission directly or indirectly. Second, it promotes novel behaviors by wild mammals who seek new food sources as their long-standing food supply becomes less dependable (Faust *et al.*, 2018). In addition to increasing the risk of spillover from wildlife to humans, as has been well documented, anthropogenic disturbance may also heighten wild apes' exposure to human pathogens (Grützmacher *et al.*, 2018b; Köndgen *et al.*, 2008; Parsons *et al.*, 2015; Rwego *et al.*, 2008).

Given the influence of humans on disease transmission dynamics at the human–animal interface, connecting human socio-behavioral contexts to models that address threats to ape survival is vital. The use of ethnography and mixed methods approaches to support human wellbeing and animal welfare promise insights into disease spillover risk and control at the human–ape interface (Dore, Riley and Fuentes, 2017; see Chapter 8). In addition, enhanced human socio-behavioral understanding is likely to help identify drivers that contribute to ape decline, such as wildlife trade, consumption and cohabitation. Creating integrated approaches that treat human values, decisions and their impacts on the physical world as one meta-system is key to future efforts in this area (Wallace *et al.*, 2015). In this context, support for effective (human) community health programs can benefit both ex-situ and in-situ ape projects.

As discussed below, people around the world are already implementing the One Health model at the human–ape interface. On the whole, however, there are limited avenues for sharing successes, failures and lessons learned. Fostering a global community of practice is essential for the creation and implementation of new, effective solutions for sustainability and resilience at the human–ape interface.

Community Health Initiatives as Drivers of Improved Ape Conservation

As highlighted in Chapter 1, many diseases that affect humans are also a threat to apes, especially those who have never had any contact with humans. A solid understanding of human health is thus necessary for assessing the risks they pose to apes. Factors that perpetuate a health risk to apes include poor human health, especially in remote rural areas where people share a common habitat or ecosystem with ape populations. In such areas, community health practices and interventions can affect human and great ape health, both positively and negatively.

A community is often described as a social unit that is organized around a

Photo: Evidence suggests that the risk of disease spillover is most strongly associated with agricultural-driven decisions such as tropical forest conversion to monoculture plantations and industrial livestock production. © Alison White

geographic area and shares common norms, customs and a sense of place.[2] Unlike clinical approaches, which focus primarily on the individual, community health considers the extent to which shared beliefs, norms and practices affect risk factors for human disease, including ill health. It seeks ways to leverage shared beliefs to ensure good health, including for the community as a whole.[3] The community health approach requires an understanding of disease processes that are relevant to the local community—as well as local health beliefs and how the community functions as a social unit (Goodman, Bunnell and Posner, 2014). Ecosystem approaches to health widen the lens to include the broader environment surrounding human and animal communities (CBD, 2020).

For the purposes of this chapter, the Human Development Index (HDI) can be seen as a quantitative measure of the environmental setting in which humans and apes interact. It is a composite index of life expectancy, education and per capita income indicators, used to rank countries in four tiers of human development. While the HDI is inadequate in terms of measuring inequality, it does recognize people and their capabilities—rather than economic growth in isolation—as the ultimate criteria for assessing the development of a country (Giannetti *et al.*, 2015; UNDP, n.d.). Many ape range states rank low on the HDI, largely due to relatively high levels of infant and child mortality, low levels of immunization for childhood communicable diseases and poor access to safe water sources, sanitation and health care services, especially in rural areas where contact with wild ape populations is most likely.

Particularly in range states with low HDI scores, prevention strategies employed in the human population can have a critical protective effect for humans and apes (Deem, 2016). For instance, vaccines against childhood communicable diseases routinely

offered at health facilities throughout range states reduce the circulation of disease in environments that humans and apes share. Prevention strategies are not universally accessible, however. To combat barriers to access, including logistical challenges and systemic inequality, ministries of health and local non-governmental organizations periodically organize mobile vaccination campaigns, often in collaboration with community leaders and other decision-makers. Still, households that are located on the outskirts of a community—and potentially closer to great ape habitats—may be far from areas where campaigns are organized, which can reduce their access to preventive care.

In addition, some children may not receive vaccines if their mothers or families mistrust immunizations or the intentions of workers providing these services. The exclusion of these or other community members not only reduces individual protection and the potential achievement of herd immunity, but it may also weaken community cohesiveness, a key factor affecting community health, with unknown consequences. A successful community health approach begins with a clear understanding of what different community members know about how immunizations work, and why they may or may not want or be able to access these services (Wiysonge, 2019). Clear communication about each immunized individual's value to the whole community can be part of a comprehensive strategy to increase understanding and acceptance of, as well as access to, the service.

Food and Nutritional Security

Food and nutritional insecurity is defined as a lack of secure access to sufficient amounts of safe and nutritious food for people's normal growth, development, and an active and healthy life (FAO, 2018; Ingram, 2020). Malnutrition affects people's immune system and their ability to ward off infection, one of a range of negative outcomes that, in turn, pose indirect health threats to ape species. Solutions include nutritional education, particularly maternal and prenatal education and food supplementation, given women's vulnerability to malnutrition. As discussed below, promoting and supporting diversified food production systems is also key to food and nutritional security.

Food security programs aimed at addressing human malnutrition often focus on ensuring adequate calorie consumption, especially during droughts or extreme weather events. Nutrition-based programs do not typically emphasize broader environmental risks, such as those associated with the use of genetically modified seeds or chemical fertilizer. Such campaigns do not generally cover the risks of wild meat consumption either, even though unsustainable hunting for wild meat threatens apes (Arcus Foundation, 2020). Since the global spread of COVID-19 in 2020, however, some of these programs have begun to take on more holistic approaches (Kumareswaran and Jayasinghe, 2022).

The Community Health Approach: Beyond Food Security

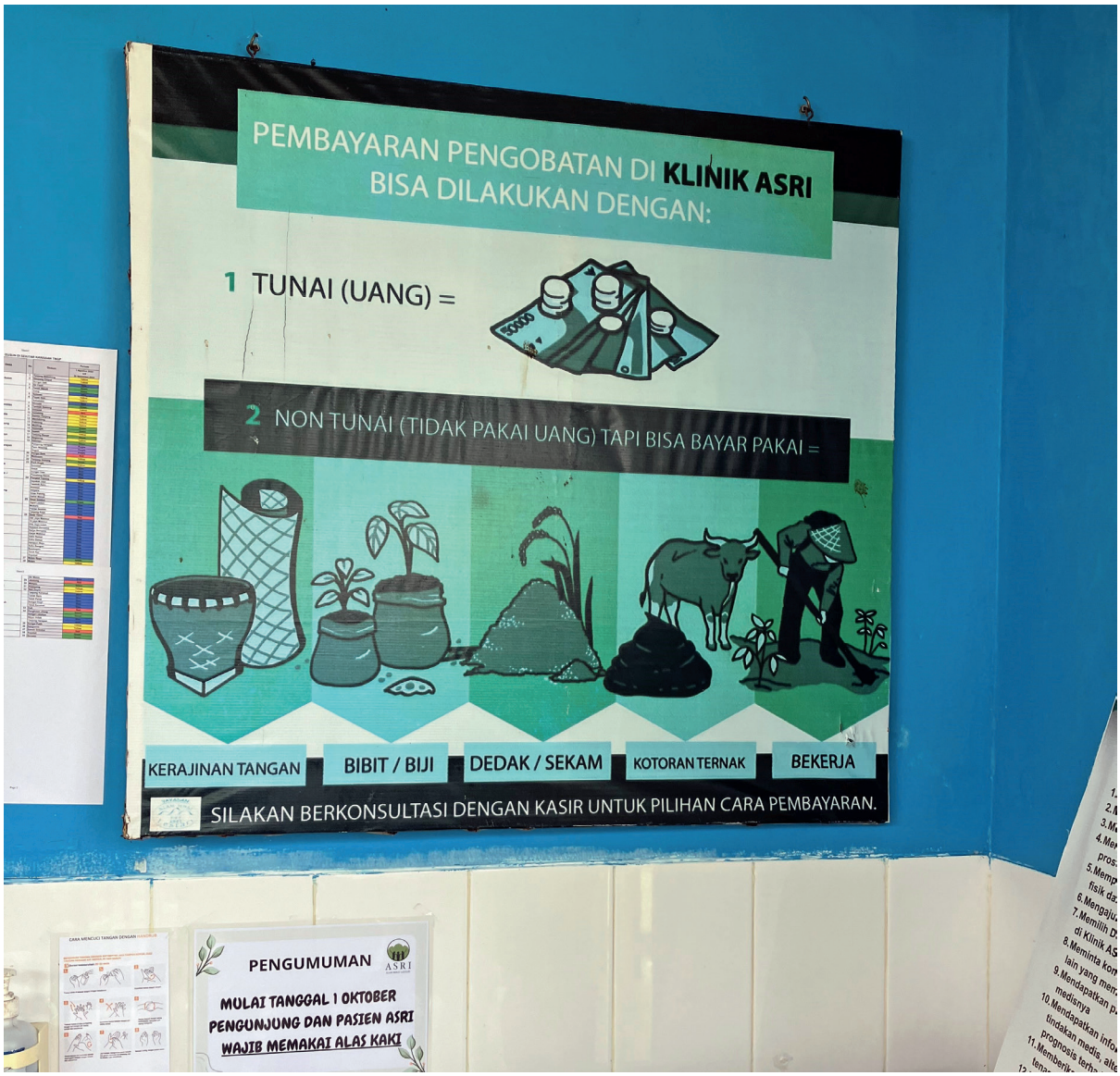
Diversified, sustainable food production systems—such as agroecology, permaculture and sustainable agriculture—can help address food and nutritional insecurity, as well as unsustainable wild meat consumption. A host of local factors affect agricultural practices and a community's potential to adequately feed itself; these include soil quality, climatic conditions and socioeconomic dynamics, such as land tenure and food sovereignty. In this context, industrial agriculture, infrastructure and poor soil management are community-wide challenges. Traditional laws about the use of community

land and resources, cultural food taboos and food preferences also play a role in community food security and nutritional health.

A community health approach considers all these factors and potential interventions to promote food security and nutritional health for all community members and the health of the community at large. For example, it would take into consideration whether land is being used unsustainably by some members and whether it is being polluted by harmful chemicals that directly or indirectly affect other community members (Ostrom and Cox, 2010).

The community health approach also leverages interventions provided by health facilities, community health workers and community-wide public health groups, while taking into account the social, economic and environmental determinants of health of a particular community. Globally, this idea has gained traction under the label

Photo: Health in Harmony and their local partner, Alam Sehat Lestari (ASRI), support human health and wellbeing by providing discounted health care services, education and alternative livelihood programs to communities that are protecting their surrounding forests. Treatment at ASRI's clinic can be paid for with cash, handicrafts, tree seedlings, grain, manure/compost or work. © Alison White



"social and environmental determinants of health" (WHO, 2012).

As discussed in the next section, the community health approach has had positive impacts around ape habitats, including when applied by conservation organizations. This volume does not examine beneficial community health outcomes outside of ape ranges, although the methodologies may be widely applicable. Relevant examples include:

- **The Konashen Community-Owned Conservation Area in Guyana**. Using ethnoprimatological techniques, this area is being studied with the aim of identifying links between sustainable primate hunting by Indigenous Peoples and cultural identity (Shaffer *et al.*, 2018). The results are being integrated into the understanding of zoonotic disease in the area (Milstein *et al.*, 2020). This research combines multiple knowledge systems from earlier work with advanced genomics to better understand and prevent emerging zoonotic diseases.
- **The PIVOT program in Madagascar**. This program serves as a framework for a model district in Madagascar, where national policies are implemented along with additional health system interventions to allow for bottom-up adaptation. The aim is to protect human health and the health and restoration of the ecosystem on which the people of Madagascar depend (Rakotonanahary *et al.*, 2021; Roberts, 2019).

One Health in Action

This section presents case studies of One Health applications at the human–ape interface, authored by the individuals who built the models. As there is no standardized method for discussing real-world One Health examples, this section uses the Berlin Principles as a unifying foundation (see Box 2.2). By highlighting relevant Principles, the case studies indicate to what degree system-based health paradigms, including ecosystem health and planetary health, converge with One Health practices.

Each case study begins with an introduction to the problem or challenge and then appraises the solutions in progress. All employ systems-based approaches and recognize that progress is incremental, accruing over iterations and, ideally, resulting in continuously improved outcomes. The authors highlight successes and failures, data gaps that could hamper decision-making, and attempts to fill them. They also explain how solutions were implemented or improved through a One Health approach. Connections between cases help to draw out the core themes.

Community Health and Ecosystem Health

Most ape species are found in the tropics, in areas that are also home to some of the world's lowest-income communities. The land is often rich in natural resources, which tend to be exploited unsustainably, to the detriment of local people and wildlife. Rapid population growth combined with increased demand for resources has led to significant anthropogenic interference in ape habitats globally (Estrada, 2013; Junker *et al.*, 2012). The consequences include habitat loss, human–wildlife conflict, increased hunting and the spread of zoonotic diseases, all of which threaten ape survival. The critically endangered mountain gorilla (*Gorilla beringei beringei*) is in particular danger (Dunay *et al.*, 2018; Hockings and Humle, 2009; Kalema-Zikusoka, Kock and Macfie, 2002).

Case Study 2.1 highlights the role of community health—which is central to the planetary health concept—in efforts to increase positive ape conservation outcomes. Case Study 2.2 is focused on ecosystem health.

CASE STUDY 2.1

Conservation through Public Health: Towards Shared Community and Gorilla Health[4]

Theme: Incorporating community health into conservation at the human–ape interface.

Applicable Berlin Principles:

- ☑ 1. Conservation
- ☐ 2. Strong institutions
- ☐ 3. Climate crisis
- ☐ 4. Ecosystems
- ☐ 5. Disease control
- ☑ 6. Biodiversity integration
- ☐ 7. Investment
- ☑ 8. Enhanced capacity
- ☑ 9. Multilevel collaboration
- ☑ 10. Awareness raising

Disciplines relevant to One Health: Public health, community development, veterinary science, ecology, ape conservation and welfare

Conservation through Public Health (CTPH)—a Ugandan grassroots non-governmental organization (NGO) and US-registered non-profit organization—was founded in 2003, after two outbreaks of skin disease occurred in mountain gorillas in 1996 and 2001/2002 (CTPH, n.d.-c; Graczyk *et al.*, 2001; Kalema-Zikusoka, Kock and Macfie, 2002). The causative agent—scabies—was traced to people with inadequate access to basic health services living around Bwindi Impenetrable National Park, Uganda (see Figure 2.3 and Chapter 1). Gorillas were probably infected when they foraged on community land and touched scarecrows made with infected clothing.

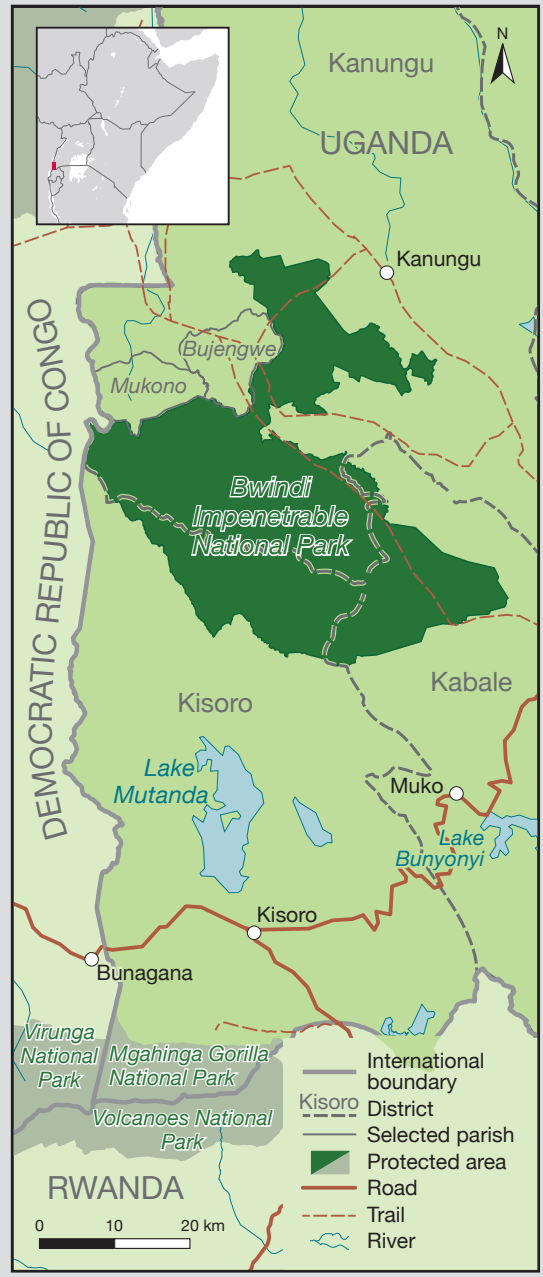
CTPH promotes biodiversity conservation by enabling people to coexist with wildlife through integrated One Health programs that improve animal health, community health and livelihoods in and around Africa's protected areas and wildlife-rich habitats. The organization had already implemented integrated wildlife and community health programs for ten years when it added "improving livelihoods" to its activities. It did so with the aim of addressing poverty that was exacerbating poor health among local communities (CTPH, n.d.-a). CTPH delivers its One Health activities through three integrated programs:

- wildlife conservation, including wildlife health and habitat conservation;
- community health with a focus on zoonotic disease prevention and control; and
- alternative livelihoods through a social enterprise called Gorilla Conservation Coffee, which provides local farmers with above-market prices for good coffee.

The majority of CTPH efforts target the area around Bwindi Impenetrable National Park and the surrounding communities. The ecosystem showcases the current challenges for great ape conservation, protected area management and human health and development. About 100,000 people live within 5 km of the park, which covers 331 km^2 (33,100 hectares) and is home to 459 (43%) of the world's mountain gorillas (*Gorilla beringei beringei*) (CTPH, n.d.-b). The main income-earning

FIGURE 2.3

CTPH Work in and around Bwindi Impenetrable National Park



Sources: Protected areas—UNEP-WCMC (2021c, 2021f, 2021i); country boundaries—GADM (n.d.); other base map detail—OpenStreetMap (n.d., © OpenStreetMap contributors, published under Creative Commons Attribution License CC BY; for more information see http://creativecommons.org)

activity in the area is subsistence farming, and up to one-quarter of all smallholder households live on less than US$ 1.25 per day (World Bank, 2018).

There is anecdotal evidence of frequent interactions between mountain gorillas and local people, as the apes forage outside the park and community members engage in unauthorized resource extraction activities in the park (Harrison *et al.*, 2015). The increasing direct and indirect contact through these interactions facilitates the transmission of commensals and pathogens, including scabies, respiratory and diarrheal diseases across the human–ape interface (Guerrera *et al.*, 2003; Rwego *et al.*, 2008; see Chapter 1).

In 2007, CTPH established Village Health and Conservation Teams comprised of community volunteers from the government-supported Village Health Team network, whose members are trained to promote health and conservation at the household and community levels. The teams promote good hygiene and sanitation, infectious disease prevention and control, family planning, proper nutrition, sustainable agriculture, and gorilla and forest conservation, including by educating their communities on the dangers of hunting and deforestation. They also document gorilla encounters near homes, enabling Human and Gorilla Conflict Resolution Teams to herd gorillas back to the park (Kalema-Zikusoka and Rwego, 2016). The Village Health and Conservation Teams reach 30,000 people in 6,000 households across 6 front-line parishes where there is conflict between people and gorillas (CTPH, n.d.-d).

The One Health approach has contributed to a reduction in human-related disease outbreaks in the gorillas. No scabies outbreaks have been recorded since 2002, and gorilla exposure to human and livestock diseases such as giardiasis has dropped (Kalema-Zikusoka *et al.*, 2018). This outcome is attributed to a combination of increased referrals of people with infectious diseases and improved health and hygiene in homes bordering park boundaries. Data collected by CTPH reveal that the percentage of pit latrines with external handwashing facilities rose from 10% to between 30% and 75%, depending on the parish. There was also a significant increase in the proportion of women who use modern contraceptives, from 22% to 67% in the first two parishes, Mukono and Bujengwe (Ainerukundo, Gaffikin and Kalema-Zikusoka, 2019). The rate is above the national average for rural areas, which did not exceed 47% in the same period (June to December 2016) (UBOS and ICF, 2018).

Gorillas are at risk from diseases of global pandemic significance, including severe acute respiratory syndrome, or SARS, and COVID-19 (Gillespie and Leendertz, 2020; see Chapter 1). CTPH's long-term presence and established relationships meant it was well placed, starting in 2020, to assist in developing activities to mitigate the impacts of the COVID-19 pandemic on mountain gorillas.

CTPH worked with the Uganda Wildlife Authority and local partners—including the Mountain Gorilla Veterinary Project/Gorilla Doctors, the International Gorilla Conservation Programme (IGCP) and the Max Planck Institute—to strengthen great ape viewing guidelines to prevent transmission of COVID-19 and other respiratory diseases between people and from people to gorillas (see Case Study 2.2). Park staff members were required to wear protective face masks and were trained to enforce hand hygiene and a 7-meter great ape viewing distance in 2014, which the Uganda Wildlife Authority increased to 10 meters in 2020. The same training was provided to Human and Gorilla Conflict Resolution Teams and Village Health and Conservation Teams (Kalema-Zikusoka *et al.*, 2021).

In the absence of tourism revenue for park edge communities, incidents of wild meat hunting increased and contributed to the killing of a gorilla by a community member who was hunting duiker of various species (*Cephalophinae*) and bushpigs (*Potamochoerus larvatus*). As a result, CTPH resumed efforts to support reformed hunters with group livestock projects as a way of discouraging them from going back to the park, while encouraging other community members not to hunt. CTPH also started a new emergency food relief program to provide fast-growing seedlings to vulnerable community members, mainly to address hunger brought about by the lack of tourists and other factors affecting the economy during the pandemic. In addition, CTPH encouraged them to go back to sustainable farming methods that they had abandoned to earn a living through the tourism industry.

The COVID-19 pandemic provided an opportunity for CTPH and IGCP to advocate for more responsible tourism involving great apes in Africa. They called for the adoption of International Union for Conservation of Nature guidelines on viewing distances to reduce the risk that tourists might get too close to gorillas (Hanes *et al.*, 2018; Mbayahi and Kalema-Zikusoka, 2020; Weber, Kalema-Zikusoka and Stevens, 2020). They also emphasized the need to support community health and hygiene and non-tourism-dependent livelihoods of people who share habitats with great apes. Further, CTPH is advocating for wildlife trade policies to help prevent future pandemics.

CTPH's overall experience of implementing activities through a One Health approach has been positive. The organization's conservation efforts have complemented government programs and initiatives by other NGOs, including ones with a focus on improving law enforcement, veterinary care, monitoring, research, and community engagement through education, health service provision and livelihoods linked to tourism. Together, these activities have helped mountain gorillas to be the only gorilla subspecies whose population is showing a positive growth trend over the past 25 years (Hickey *et al.*, 2019b). A recent study based on population monitoring estimates that the population in the entire Virunga Massif is growing at a rate of about 3% per year (Granjon *et al.*, 2020a).

CASE STUDY 2.2

Yayasan Ekosistem Lestari and Gorilla Doctors: Ecosystem Health in Africa and Asia[5]

Theme: Applying ecosystem health methods within a One Health approach to promote ape-focused conservation and welfare.

Applicable Berlin Principles:

- ☑ 1. Conservation
- ☐ 3. Climate crisis
- ☑ 5. Disease control
- ☐ 7. Investment
- ☐ 9. Multilevel collaboration
- ☑ 2. Strong institutions
- ☑ 4. Ecosystems
- ☑ 6. Biodiversity integration
- ☐ 8. Enhanced capacity
- ☑ 10. Awareness raising

Disciplines relevant to One Health: Community development, veterinary science, public health, ecosystem management, reintroduction biology, ecosystem health

Yayasan Ekosistem Lestari

Yayasan Ekosistem Lestari (YEL)—the Sustainable Ecosystem Foundation—was founded in 2000 with the vision "to preserve the environment with sustainable benefits for the whole community" (YEL, n.d.-b). One of YEL's main programs is the Sumatran Orangutan Conservation Programme (SOCP), a collaboration with the Swiss PanEco Foundation and Indonesia's Ministry of Environment and Forestry. Another program is the Environmental Education Centre Bohorok, in Bukit Lawang, North Sumatra (YEL, n.d.-a, n.d.-b; see Figure 2.4). Both were established in response to the massive impact of large-scale deforestation on Sumatra's rainforest and the

FIGURE 2.4

Yayasan Ekosistem Lestari Work in North Sumatra, Indonesia

Sources: Protected areas—UNEP-WCMC (2021d); country boundaries—GADM (n.d.); other base map detail—OpenStreetMap (n.d., © OpenStreetMap contributors, published under Creative Commons Attribution License CC BY; for more information see http://creativecommons.org)

endemic fauna it supports (YEL, n.d.-b). Deforestation has a direct impact on ecosystem health because it reduces biodiversity and thus weakens the ecosystem's ability to cope with challenges.

The SOCP employs the One Health paradigm by focusing on the ecology, health and welfare of orangutans in its ex-situ conservation program, which covers the rescue, rehabilitation and reintroduction of ex-captive orangutans to establish new viable wild populations for its in-situ conservation program. This program utilizes knowledge on disease spread between orangutans and other species, including humans, to provide risk-based data on disease and health issues (SOCP, n.d.-d). To enable rehabilitated orangutans to return to a life in Sumatra's tropical rainforests, the YEL team uses the data as part of a One Health approach that combines community development in ecosystem health and support for law enforcement.

Since 2002, more than 350 orangutans have arrived at the SOCP's Orangutan Quarantine and Rehabilitation Centre in North Sumatra for the health screening they need prior to joining the rehabilitation program. In the same time, nearly half (more than 170) of the orangutans have been released to Bukit Tigapuluh National Park in Jambi (with the help of the Frankfurt Zoological Society) and around 100 have been transferred to the Jantho Pine Forest Nature Reserve in Aceh, in release operations wholly managed by YEL (SOCP, n.d.-a, n.d.-d).

At the YEL reintroduction center in Jantho, the SOCP team conducts remote surveys to monitor habitat and identify threats, assess the health and welfare of the released orangutans, and evaluate dispersal of the reintroduced orangutan population—the latter as an indicator of the ecosystem health service the species provides as a seed disperser (McConkey, 2018; SOCP, n.d.-b). The post-release monitoring team consists of YEL staff members from local villages, who are trained in monitoring orangutan behavior and conducting phenology surveys of forest composition and fruit availability. The habitat monitoring team initially comprised only YEL staff, but by mid-2019 all the habitat monitoring team members were local residents working part-time. At the end of 2019 the habitat monitoring team was fully handed over to the local community under what is called the Jantho Community Ranger program, with members representing seven local villages around the periphery of the Jantho Nature Reserve. Related data analysis is still carried out using the expertise of YEL personnel.

The plan is to transfer knowledge and the capacity for data analysis to the Jantho Community Rangers, to enable the team to carry out habitat monitoring independently, wherever and whenever needed. Via the Jantho program, a sustainable habitat monitoring team is gradually being established, with members from the adjacent communities trained in species management, habitat monitoring and protection methods, and data analysis. This work also helps the local population develop an understanding of a healthy ecosystem.

The key for orangutan conservation is protection of their remaining habitat. Rescue and rehabilitation projects cannot guarantee the survival of orangutans in the wild without the protection of the rainforests and the existing wild populations.

The SOCP's in-situ conservation focuses on wild orangutan populations in Sumatra in several ways. The SOCP manages three field monitoring stations, two in the Leuser Ecosystem, home to the Sumatran orangutan (*Pongo abelii*), and one in the Batang Toru Ecosystem, home to the recently described Tapanuli orangutan (*Pongo tapanuliensis*) (SOCP, n.d.-c). In these landscapes, students and field assistants can study orangutan behavior and ecology as well as their interaction with their forest habitat. Their research helps to inform the One Health approach by providing vital behavioral ecology information, integrated with disease surveillance data gathered during rehabilitation. These data are critical for assessing disease spread risk through the orangutan population.

YEL and the SOCP are taking a holistic approach to tackling the diverse challenges facing the health of the Leuser Ecosystem. They do so by working on the interconnected issues of orangutan conservation, habitat protection and monitoring, by promoting and encouraging sustainability, and by actively supporting direct community involvement in preserving healthy ecosystems.

Gorilla Doctors' Health Programs

Numerous international and local non-governmental organizations are working together to conserve the mountain gorillas (*Gorilla beringei beringei*) and Grauer's gorillas (*Gorilla beringei graueri*), as well as their habitat in the Democratic Republic of Congo (DRC), Rwanda and Uganda (see Figure 2.5). Part of the focus is on disease control, as described in Case Study 2.1, with different projects targeting the community, rangers, researchers and tourists. This case study focuses on Gorilla Doctors' employee health program.

Michael Cranfield, who served as Gorilla Doctors' project director from 1998 to 2019, ranked disease as the biggest threat to mountain gorillas:

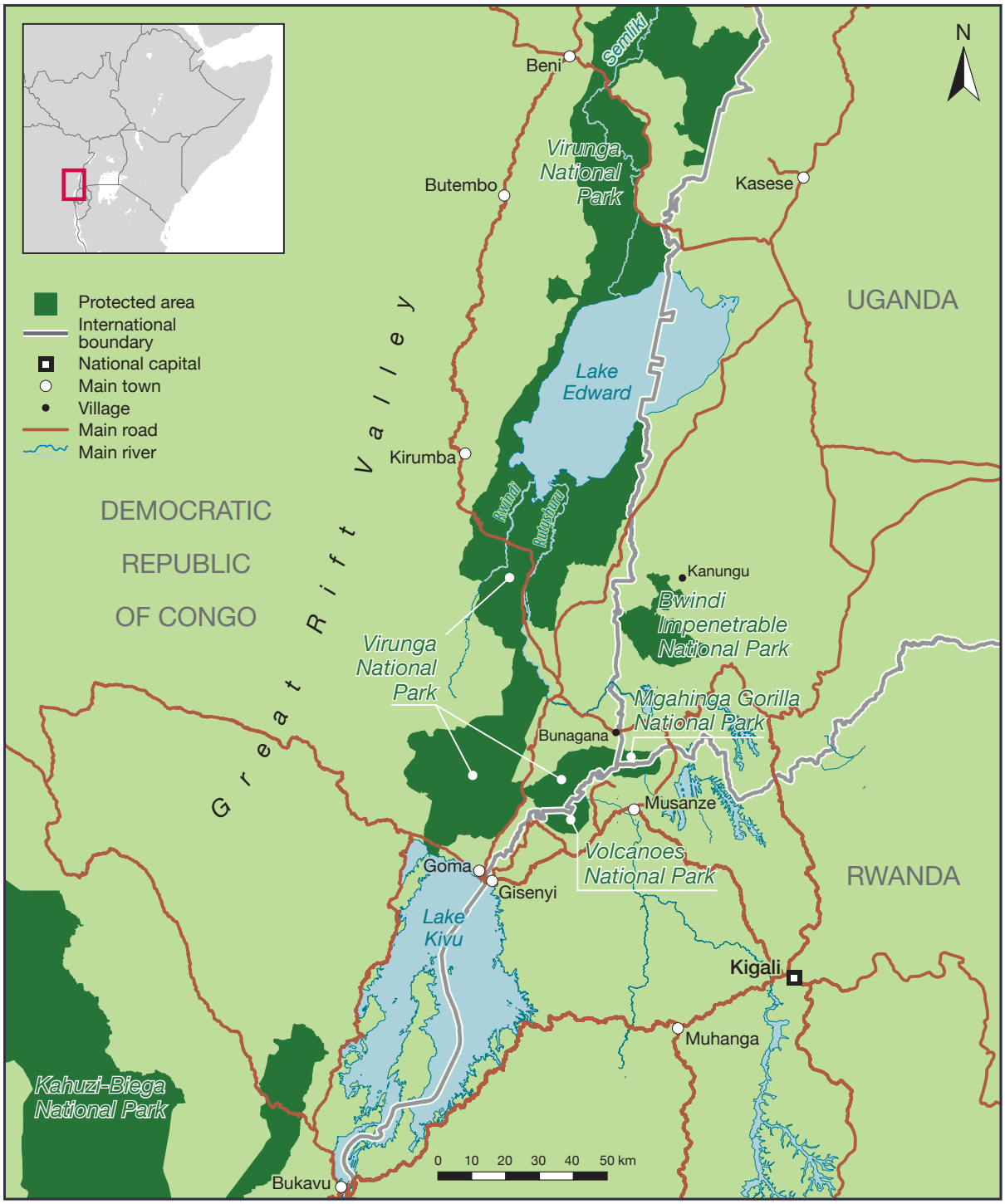
> Bush meat and logging were for a long period the two leading causes of decreasing gorilla numbers in general, with disease being third. Because the mountain gorillas are in protected areas, the first two factors take a backseat to disease (Nolen, 2006).

Conservation workers and tourists spend time with habituated gorilla groups on a daily basis. Gorillas can also venture outside protected areas, where they may come into contact with local people and domestic animals. The long-term health of mountain gorillas cannot be ensured without addressing human and domestic animal health. As a result, Gorilla Doctors approaches gorilla conservation medicine from a One Health perspective (Gorilla Doctors, n.d.-e). Specifically, the organization undertakes activities as part of a suite of One Health initiatives, including:

- Facilitating annual health screenings, follow-up care and health education for people who work in the national parks through an employee health program (see below).

FIGURE 2.5

Gorilla Doctors Work in the DRC, Rwanda and Uganda



Sources: Protected areas—UNEP-WCMC (2021c, 2021f, 2021i); country boundaries—GADM (n.d.); other base map detail—OpenStreetMap (n.d., © OpenStreetMap contributors, published under Creative Commons Attribution License CC BY; for more information see http://creativecommons.org)

- Providing preventive health programs for livestock and pets living near the gorilla habitat and educating their owners about best animal care practices.
- Facilitating a feral dog control program near the gorilla habitat to reduce the number of feral dogs and cats.
- Conducting pathological examinations of tissues collected during post-mortem examinations of deceased gorillas and other wild animals with whom gorillas share the ecosystem, to determine the causes of death.
- Carrying out targeted sampling and testing of priority wildlife taxa for emerging infectious disease pathogens that pose the greatest health risk to people and gorillas, largely through collaborative research projects with universities and other research institutions, as a way of informing best practices for highly infectious disease prevention and preparedness.
- Conducting research to investigate the linkages between the health of gorillas, humans and other animals.
- Making recommendations to government and local authorities about best practices for managing a healthy gorilla population based on research findings.
- Providing local, regional and international veterinary, medical, public health, epidemiology and environment students and professionals with opportunities for internships, volunteering, training and research.

Employee Health Program

To reduce the risk of disease transmission between people and gorillas, Gorilla Doctors facilitates annual health screenings and follow-up care for people who come in contact with gorillas as part of their work to protect these populations in national parks (Gorilla Doctors, n.d.-c). Great ape site staff and tourism support workers such as rangers, guides and porters spend many hours in the forest tracking habituated great apes. They are also in indirect contact with unhabituated apes, simply by virtue of their shared use of habitat. While researchers and veterinarians may be fewer in number and perhaps spend less time in the forest, they have close contact with individual animals and groups as they collect data or treat ill or injured animals (Gilardi *et al.*, 2015).

Each year, hundreds of rangers, trackers, researchers and others who work in the parks participate in Gorilla Doctors' employee health program. Currently, this program is offered to people who work in Volcanoes National Park, Rwanda, and Virunga and Kahuzi-Biega National Parks, DRC. The program is administered in conjunction with local hospitals, which provide the necessary facilities and medical staff. Nearly 300 national park workers and more than 2,000 family members participate in the health screening and health education programs. Through this program, conservation employees:

- undergo physical examinations and screening for infectious and chronic diseases such as tuberculosis;
- are immunized against infectious diseases such as measles, polio and rabies;
- receive treatment or referrals for additional care if they are sick;
- are linked to government programs that provide treatment for chronic diseases, such as antiretroviral drugs if they are living with the human immunodeficiency virus (HIV);
- participate in health education programs; and
- bring their families to receive treatment for tropical diseases such as intestinal parasites, as well as counselling about hygiene, family planning and HIV prevention.

Due to the close phylogenetic relationship between humans and apes, great apes are susceptible to human diseases, especially those to which they have no natural immunity due to a lack of previous exposure, such as measles, polio, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and tuberculosis (Ferber, 2000; Gillespie and Leendertz, 2020; Gillespie, Nunn and Leendertz, 2008). Until recently, evidence of direct disease transmission to wild apes was limited to bacterial and parasitic infections; however, several new studies provide evidence of direct viral transmission between humans and apes.[6] Also of concern are pathogens that may remain dormant in the environment for extended periods, such as some intestinal parasites (Gillespie *et al.*, 2010; Zommers *et al.*, 2013; see Chapter 1).

Best practices for any great ape conservation employee health program include the following:

- Examination of employees before or at the time of hire to determine eligibility for specific job responsibilities, such as fieldwork, but with permission from the employee to prevent employment discrimination against sick individuals, protect patient confidentiality and adhere to ethics guidelines.
- Fecal testing for gastrointestinal parasites and immediate treatment of employees if needed, for the following reasons: employee infection rates tend to be high; employees are the people most likely to defecate in great ape habitat because they are often in the forest all day; treatment regimens are standard; drugs are inexpensive and widely available; and gastrointestinal pathogen transmission between people and great apes has been documented (Gilardi *et al.*, 2015; Parsons *et al.*, 2015).
- Recommending and directing employees to appropriate hospitals and clinics for treatment of any medical conditions or infections detected through the employee health program, combined with the referral of employees with confirmed chronic disease cases to national health programs or to other local institutions for more complex or emergency care.
- Extending employee health program services to family members to help achieve overall objectives—wherever the requisite financial, human and other resources are in place. In Rwanda, for example, there is a comprehensive national health insurance scheme for all citizens, which allows for referrals for chronic and complicated medical conditions detected through the employee health program.

In contrast, the bulk of medical bills associated with such referrals in the DRC can only be covered through fundraising.

Partnerships for Community and Animal Health Programs

Gorilla Doctors understands the interconnectedness between humans, domestic animals, wildlife and other elements in the ecosystem as determinants of health, while also recognizing the need for a multisectoral approach (Gorilla Doctors, n.d.-c). Consequently, the organization has partnered with local human and animal health care providers to participate in One Health programs in the gorilla conservation area. Over the past few years, this work has involved raising community awareness, vaccination, disease surveillance, research and advocacy, including through the following initiatives:

- surveillance for zoonotic diseases of public health importance;
- veterinary support to rural communities living within or close to protected areas;
- support for capacity building of local animal health professionals, along with veterinary student training and internship opportunities;
- massive dog and cat vaccination campaigns to try to eradicate human and animal rabies;
- vector-borne disease control through spraying of mosquitos and other vectors; and
- advocacy for community action in One Health and engagement of local government and local communities on improved domestic waste management, especially around conservation areas.

The Role of Capacity Development

The Global Health Security Agenda identifies a critical lack of adequately trained wildlife health professionals around the world (GHSA, 2020). For projects such as those illustrated above to be successful, effective capacity development programs linking One Health principles to veterinary health and conservation management practice are thus needed.

The Pan African Sanctuary Alliance in Africa and the Orangutan Veterinary Advisory Group in Southeast Asia have facilitated ape-focused capacity building programs for several years (OVAG, n.d.; PASA, n.d.-b; see Chapter 4). These programs focus on practitioner education and empowerment through the creation of health-focused networks to increase the capacity to improve ape health. They are designed to provide veterinary-led training that advocates the inclusion of One Health principles in ape-focused conservation action plans (Unwin *et al.*, 2022; see Case Study 2.3). They pair community-based domestic animal, human and wildlife health practitioners with academics from all continents and practitioners within the International Union for Conservation of

CASE STUDY 2.3

A Team-Based Approach to Ape Health Networks to Develop an Ape-Focused Global Health Initiative

Theme: Building capacity to allow for the application of One Health approaches.

Applicable Berlin Principles:

- ☐ 1. Conservation
- ☑ 2. Strong institutions
- ☐ 3. Climate crisis
- ☐ 4. Ecosystems
- ☑ 5. Disease control
- ☐ 6. Biodiversity integration
- ☐ 7. Investment
- ☑ 8. Enhanced capacity
- ☑ 9. Multilevel collaboration
- ☑ 10. Awareness raising

Disciplines relevant to One Health: Veterinary science, public health, tertiary education practice, science communication, succession planning

Together, the Pan African Sanctuary Alliance and the Orangutan Veterinary Advisory Group (OVAG) represent an ape-focused global health initiative. They are capacity-strengthening and expertise networks that synergize efforts from multiple organizations, all of which aim to improve their individual and collective impact on ape welfare and conservation.

To achieve maximum impact, the organizations involved in this network use interdisciplinary One Health principles whenever approaches or aims overlap. For example, practitioner mental health and resilience are vital to maintaining a community of practice that can sustain One Health programs. In nearly all ape health contexts, practitioners who inform welfare assessments of ape populations can benefit from an understanding of their own mental states and behaviour that could drive disease risk, including in relation to the transmission of zoonotic disease (see Chapter 8).

Network members build capacity via didactic and problem-based workshops, practical laboratory sessions, online advisories, and as advocates between participants and their organizations. As a collective,

the network provides direct input into conservation management at the organizational and government level. Capability is enhanced through a forum, which empowers ape health practitioners and academics to formulate plans relevant to all wildlife health management needs. As a rule, these plans are respected and utilized by decision-makers. The assumption—based on global One Health guidance from the World Organisation for Animal Health and the One Health High-Level Expert Panel—is that this consolidation of experts from a wide variety of organizations improves individual impact in conservation and welfare efforts (OHHLEP *et al*., 2022; WOAH, 2021).

In evaluations carried out over the past decade, the OVAG program has been found to help improve the quality of participant outputs on an iterative basis (Unwin *et al*., 2022). OVAG's integration of One Health programs into welfare and conservation efforts has led to improved disease mitigation strategies in both in-situ and ex-situ populations, particularly by linking public health and environmental disease issues that contribute to the protection of apes, their habitat and human health. Utilizing community engagement platforms such as WhatsApp is a core approach of the United Nations strategy and is embedded in the Sustainable Development Goals and the Global Health Security Agenda (Armstrong-Mensah and Ndiaye, 2018; UN, 2019).

Every network participant has a responsibility and role to play, including wildlife center administration and participating staff, local public health representatives, and community leadership and members. Key goals of the network's internet information hub, which allows open access to all participants simultaneously, are the longevity of its hardware, software and content (capacity), as well as human participant capability long into the future. With respect to the transfer of knowledge, the hub's features are aimed at minimizing inequalities among staff members from different stakeholder organizations and among local communities. OVAG has already registered evidence of at least partial achievement of these desired outcomes, based on increased staff retention, successful train-the-trainer initiatives and positive reviews from network participants, over 80% of whom said that their participation was either critical or very important in shaping their decision-making processes (Unwin *et al*., 2022).

Nature, the American Association of Zoo Veterinarians and the European Association of Zoo and Wildlife Veterinarians networks. In 2020, these networks were further integrated via a combined concern over the SARS-CoV-2 threat to all apes, via a new online technical service, the Non Human Primate COVID-19 Information Hub (University of Minnesota, n.d.-b).

Disease risks can only be mitigated effectively if capacity building on One Health extends beyond conservation to cover the extractive industries and industrial agriculture sectors. As discussed in the next section, ape habitats face significant threats from land use changes associated with resource extraction and agricultural expansion (Arcus Foundation, 2014, 2015).

Resource Management and Land Use

Agriculture is the biggest cause of habitat loss in ape range countries, particularly in Asia, given the global demand for oil palm products (Estrada *et al.*, 2017; Williams *et al.*, 2021). Significant damage is also done by the extractive industries, such as large-scale logging and mining, as well as clearance for large-scale infrastructure. Ape habitats are also threatened by unsustainable local-level exploitation and extraction of resources, both of which are driven by a range of actors.

The links between threats driven by various land uses are complex. For instance, the expansion of industrial agriculture in one area may drive communities from their land and push them to farm within a protected area. Similarly, the establishment of a national park may prevent communities from accessing traditional food sources within the forest and push them into other economic activities, which ultimately threaten ape habitat. Many people who live around protected areas—including some who may have been evicted when such areas were created—still rely on accessing protected ape habitats for non-timber forest products such as firewood, charcoal, food, fodder, thatch and medicines. Effective implementation of the One Health approach requires consideration of the diverse land uses driven by different sectors at different scales, as well as the complex links between them.

Land use changes not only risk degrading environmental health, but they can also impact ape health through loss of habitat, loss of preferred diets, heavy metal contamination and the introduction of disease (Estrada *et al.*, 2017). In addition, apes may

be attracted to newly disturbed sites due to the availability of food (cultivated or herbaceous secondary growth), which can further increase their exposure to hazards such as human and livestock excrement, as well as mining pollution (Ontl, 2017). Moreover, increased contact between apes, people and domestic livestock can lead to the transmission of diseases (Parsons *et al.*, 2014; Spelman *et al.*, 2013). One Health approaches have enabled positive ape health and conservation outcomes in the context of land use changes, however. Case Study 2.4 introduces collaborative approaches that successfully integrate land use practices with ape conservation programs.

CASE STUDY 2.4

Using One Health to Link Land Use to Ape Health

Theme: Balancing approaches to land use with ape health and conservation needs.

Applicable Berlin Principles:

- ☑ 1. Conservation
- ☑ 2. Strong institutions
- ☑ 3. Climate crisis
- ☑ 4. Ecosystems
- ☐ 5. Disease control
- ☑ 6. Biodiversity integration
- ☑ 7. Investment
- ☐ 8. Enhanced capacity
- ☐ 9. Multilevel collaboration
- ☑ 10. Awareness raising

Disciplines relevant to One Health: Community health, land tenure and environmental law, community conservation, resource management

Conservation organizations have developed different ways to mitigate the impacts of land use changes caused by agriculture and resource extraction on ape habitats and other wildlife areas. These include improved land tenure, land use planning, resource management, sustainable use and legislation for conservation (TAWIRI, 2018). Other initiatives involve working with local communities to improve their health, education and livelihoods, as well as advocacy and campaigns against destructive industrial activities and their financing. These approaches—which often focus on addressing human rights and land use issues—tend to entail collaboration between conservation organizations, local communities, private-sector firms and governments. Multisectoral and multidisciplinary approaches are required to coordinate holistic and sustainable solutions to ecosystem, human and animal health.

Improving Human Health and Wellbeing

A successful approach to reducing illegal logging and forest loss on Borneo is implemented by the US-based planetary health organization Health in Harmony. The organization focuses on improving human health and wellbeing by providing discounted health care services, education and alternative livelihood programs to communities that are protecting their surrounding forests (HiH, n.d.). A ten-year study of the Gunung Palung National Park indicates that this approach

FIGURE 2.6

Health in Harmony Work in Central and West Kalimantan, Indonesia

Sources: Protected areas—UNEP-WCMC (2021d); country boundaries—GADM (n.d.); other base map detail—OpenStreetMap (n.d., © OpenStreetMap contributors, published under Creative Commons Attribution License CC BY; for more information see http://creativecommons.org)

reduced illegal logging and simultaneously improved health care access and health outcomes (Jones *et al.*, 2020; see Figure 2.6). The focus on improving human health expanded to the Bukit Baka Bukit Raya National Park in Indonesia, where Health in Harmony partnered with the UK based wildlife welfare group International Animal Rescue, which coordinates orangutan rescue and rehabilitation (Finley, 2019).

Buffer Zones

Buffer zones are areas of controlled resource extraction around protected areas. They provide benefits to local communities while reducing pressures associated with human encroachment on wild spaces (Nepal and Weber, 1994). In Bwindi Impenetrable National Park in Uganda, the International Union for Conservation of Nature and UNESCO support the demarcation of multiple-use zones for regulated harvest of certain resources (such as honey and medicinal plants) by authorized resource users (Harrison *et al.*, 2015). Despite these allowances, however, illegal resource extraction continues in some areas. These incursions increase the risk of human–wildlife conflict and disease transmission to gorillas. Drivers of unauthorized resource extraction include poverty and resentment linked to historic evictions from the park, "crop-raiding" by wildlife and perceived unfairness in benefit sharing (Harrison *et al.*, 2015). Local knowledge and engagement in the establishment of buffer zones is necessary for their success (Nepal and Weber, 1994). Alternative approaches to buffer zones include community-managed forests in land-sharing arrangements (Estrada *et al.*, 2017). In Bwindi, conservation organizations such as Gorilla Doctors, the International Gorilla Conservation Programme and the World Wide Fund for Nature foster local engagement to minimize encroachment into the forest.

Agricultural Innovation and Transformation

Another approach to reduce habitat destruction and resource extraction in ape-range countries is to improve livelihoods for small- to medium-scale farmers. Agriculture is the most common source of livelihoods for these communities (Plumptre *et al.*, 2004). Improvements to farming practices can be achieved through conservation agriculture and revitalization of some of the traditional farming techniques that were eroded by the green revolution (FAO, n.d.-b; John and Babu, 2021). These approaches, utilised by stakeholders such as the International Livestock Research Institute and the UN's Food and Agriculture Organization, advocate reduced tillage, permanent soil coverage, reduced use of agrochemicals, increased plant diversity and supporting ecosystem services with trees and other natural features (Arcus Foundation, 2015; FAO, n.d.-a; see Box 1.4). Improvements in livestock farming can be secured through enhanced nutrient cycling based on maintaining association between crops and livestock and controlling livestock disease through biosecurity, vaccination and disease-resistant breeds (ILRI, 2019). Smallholder farmers can benefit from new technologies to improve production, including mobile phone innovations; access to markets and reliable value chains for produce; and education in new business models (ILRI, 2019). The combined benefits of improving environmental and livestock health through a holistic approach include enhanced livelihoods and hence better human health and nutrition, as well as a reduction in the pressure on apes and their habitats.

Community-led Conservation

It is widely recognized that Indigenous Peoples and Local Communities (IPLCs) are central to effective conservation of nature. Ranging from community conservancies and community forestry to integrated conservation and development, a wealth of holistic approaches attempt to reconcile the needs of species and ecosystems with the cultural, social and economic wellbeing of IPLCs. "Territories of life"—a term used by IPLCs that is gaining traction within the conservation sector and among international and local NGOs—refers to areas governed and conserved by IPLCs according to their particular cultures, governance systems and practices. The *Territories of Life* report presents a series of case studies that showcase holistic approaches used by IPLCs to protect their territories and the life they harbor. These approaches involve conducting participatory mapping and securing land rights; revitalizing environmental knowledge and language, including about how to live alongside and care for species and their habitats; strengthening governance systems and developing conservation by-laws; and supporting nature-friendly food production systems and livelihoods (ICCA Consortium, 2021). The report links these approaches to the improved protection of ecosystems and the species they support, as well as to improved health and wellbeing of communities. Several case studies focus on territories of life that are home to apes, including Hkolo Tamutaku K'rer (the Salween Peace Park) in Myanmar, Kisimbosa in the DRC and Yogbouo in Guinea (ICCA Consortium, 2021).

Internal Health Systems: Microbiomes and Ape Health

Biodiversity loss can both promote and be affected by emerging infectious diseases, with great potential for shaping human history through epidemics and pandemics (Keesing *et al.*, 2010; Nicholson, 2016). Managing these threats depends as much on effective internal microcosms that can interpret changes in the world and respond appropriately, as it does on external ecosystems. In this context, One Health practice is relevant to successful immune and microbiome system operation.

A significant part of the internal microcosm is the gut microbiome. Evidence suggests that, in humans, health status and particularly gut microbiome dysbiosis (imbalance) may be driving clinical signs. Confounders of this relationship include lifestyle factors such as diet, including fiber intake, which is driven by socioeconomic status in humans; behavior, including periods of stress or conduct risky to health; demographic factors such as race, host genetics and geography; and the use of antibiotics (Clayton *et al.*, 2016). Dysbiosis can occur for several reasons (which may apply concurrently), including a reduction in certain gut microbes; an increase in harmful infectious pathogens; increases in the prevalence of an ordinarily commensal bacterium; and a decrease in microbial diversity (Gagliardi *et al.*, 2018). Further, the status of the human gut microbiome has been linked to chronic diseases such as autoimmune and inflammatory conditions that affect the gastrointestinal system, such as ulcerative colitis and Crohn's disease, colorectal cancer, diabetes, Kwashiorkor, non-alcoholic fatty liver disease and obesity (Clayton *et al.*, 2016; Gevers *et al.*, 2014; Turnbaugh *et al.*, 2008; Yang and Jobin, 2014).

While investigations into ape microbiomes remain a nascent research area, studies in monkeys show convergence of

CASE STUDY 2.5

The Primate Microbiome Project: One Health and the Individual Microcosm

Theme: Linking internal health to One Health.

Applicable Berlin Principles:

- ☑ 1. Conservation
- ☐ 3. Climate crisis
- ☑ 5. Disease control
- ☐ 7. Investment
- ☐ 9. Multilevel collaboration
- ☑ 2. Strong institutions
- ☐ 4. Ecosystems
- ☐ 6. Biodiversity integration
- ☑ 8. Enhanced capacity
- ☑ 10. Awareness raising

Disciplines relevant to One Health: Microbiology, veterinary science, evolution, medical science, public health

There are currently no data on the effect of gut microbiome changes on non-infectious and infectious gastrointestinal disease in apes—nor is there even knowledge on whether changes occur. The Primate Microbiome Project was established to develop a systematic map of variation in microbiome structure and function across all primates and to relate the findings to primate behavior, conservation, evolution and health (PMP, n.d.).

For rehabilitant orangutans, gastrointestinal illness represents a significant barrier to successful release into the wild. Indeed, anecdotal and peer-reviewed evidence indicates that clinical gastrointestinal disease is an important issue in all captive orangutans (Strong *et al.*, 2016). Unpublished data highlight that gastrointestinal upset in orangutan rehabilitants, without evidence of a confirmed pathogenic cause or origin, appears to worsen during the translocation process and following release into the wild (Y.S. Saraswati and C. Nente, personal communication, 2019). Endoparasites in clinically healthy wild and semi-captive orangutans have also been reported; these may exacerbate clinical signs due to a dysbiosis—an imbalance of the gut microbiome (Labes *et al.*, 2010; Mul *et al.*, 2007).

Since orangutans live in captive, semi-captive and wild settings and some are (re-)released into the wild, there is an opportunity to examine microbial transmission and determine how resilient or susceptible a microbiome is based on lifestyle. Studies can consider whether and under what circumstances orangutans in captivity acquire human microbes, given that such transfers have been documented in sanctuary chimpanzees (Schaumburg *et al.*, 2012). Daily record-keeping in such environments allows for monitoring of the effects of diet and other lifestyle factors on microbiome composition. One lifestyle factor is antibiotic exposure, which is prevalent in captive settings both in and outside of range countries and has been demonstrated to be a risk factor for wild chimpanzees (Parsons *et al.*, 2021).

In 2019, a collaborative One Health mapping project was launched by the Primate Microbiome Project, the British and Irish Association of Zoos and Aquariums, the University of Birmingham and the Orangutan Veterinary Advisory Group (OVAG) to investigate this issue from an integrated perspective, in both in-situ and ex-situ scenarios. The aim was to begin answering the question, "What does the gut microbiome look like in a healthy orangutan?" In 2022, following delays linked to COVID-19, a pilot study began to assess the microbiome of orangutans housed in a UK zoo. Perhaps more importantly, this project has resulted ▸

in the training of OVAG participants in DNA extraction, polymerase chain reaction and gene sequencing to continue investigations in the field.[7]

In the future, this project aims to examine gut microbiome interactions between orangutans and humans at points of stress in a captive orangutan's life—for example, after confiscation and the initial rehabilitation process; during transportation between zoos; and during release back into the wild—and compare those to the wild or "normal" microbiome. The gut microbiome of wild populations has not yet been investigated either; one of the initial tasks of this study is to examine the "normal" microbiome of Bornean orangutans (*Pongo pygmaeus*) in Sabah and Sumatran orangutans (*Pongo abelii*) in the Leuser Ecosystem of Indonesia. Data gathered from the following perspectives are to inform orangutan conservation management decisions:

- **Biological perspective:** How is gut health affected by microbial diversity, dietary traits and behavior? What are the effects of different habitats on the orangutan microbiome (such as disturbed forests compared to intact habitats)? Does the microbiome of infants who drink breast milk differ from those of infants who are fed formula?
- **Health perspective:** Is gut microbial diversity species-specific and linked to a healthy gut? Is diversity a good indicator and possible driver of susceptibility to gastrointestinal pathogens?
- **Evolutionary perspective:** What are the effects of host genetics versus lifestyle factors on shaping the gut microbiome? What impact does acquisition of human microbes have on orangutans in captive and semi-captive settings?
- **Conservation perspective:** Are humans introducing microbiome changes in wild populations that could lead to increased disease risk? Are humans creating an antibiotic resistance issue through conservation reintroductions? Do the microbiomes in captive and semi-captive orangutans differ from those of wild orangutans? If so, what are the potential negative consequences for populations in the long term? Moreover, what could be the reasons for the differences—could they be linked to changes in diet, exposure to humans, artificial circumstances, antibiotic usage, changes in social structure or the reduction in opportunities to acquire microbes from other individuals?

their gut microbiome with that of their human caregivers (Clayton *et al.*, 2016, 2018). This trend cannot just be due to diet, as zoo-based diets for primates are arguably much better than those of many humans in the developed world (Muegge *et al.*, 2011; Nagpal *et al.*, 2018). What, then, are the environmental factors that drive this convergence? Are they the same drivers that have changed the human microbiome over the past several thousand years—water quality, pollution and behavior? Case Study 2.5 explores a One Health project that examines potential links between external drivers, the orangutan microbiome, and orangutan health at the individual and population levels.

Translational Medicine and Ape Health

One Health can be interdisciplinary, multidisciplinary and translational in its approach. Translational medicine expedites the discovery of new diagnostic tools and treatments by using a multidisciplinary, highly collaborative approach. It links medical research, medical practice and community to produce a holistic approach to medicine, linking patient to environment. Case Study 2.6 illustrates how this holistic approach is applied to ape cardiac health research to improve both clinical and animal management decisions. Translational medicine encourages using methodologies across species to confirm cardiovascular "normals" and abnormalities.

Conservation Projects and the Impact of Human Activity on Ecosystem Health

The real and perceived risks of wildlife-associated diseases for human and domestic animal health can potentially erode public support for wildlife conservation itself (Buttke, Decker and Wild, 2015). Wildlife conservation projects are therefore ideally placed to inform public perceptions of disease risks, particularly through community engagement and related efforts in environmental protection. Conservation practice itself can become more effective at mitigating harm by recognizing and understanding the complexity of social impacts on the environment and on wild animal populations and individuals, despite the lack of

CASE STUDY 2.6

International Primate Heart Project: Translational Medicine in Ape Health

Theme: Indicating the importance of the translational medicine approach to One Health.

Applicable Berlin Principles:

- ☐ 1. Conservation
- ☑ 2. Strong institutions
- ☐ 3. Climate crisis
- ☐ 4. Ecosystems
- ☑ 5. Disease control
- ☐ 6. Biodiversity integration
- ☐ 7. Investment
- ☑ 8. Enhanced capacity
- ☐ 9. Multilevel collaboration
- ☐ 10. Awareness raising

Disciplines relevant to One Health: Medical science, veterinary science, capacity building, tertiary education

Historically, cardiac disease has been shown to be a condition of concern in ex-situ primate populations, particularly in North American and European zoos (Lowenstine, McManamon and Terio, 2016; Strong et al., 2016). In captive apes, idiopathic myocardial fibrosis and cardiomyopathy were found to predominate. In humans, idiopathic myocardial fibrosis is abnormal and pathogenic; in chimpanzees, however, it may be normal. Similar cardiomyopathy lesions are rarely found in wild apes. Vascular changes in the heart and kidneys and aortic dissections in captive gorillas and bonobos suggest that hypertension may be involved in pathogenesis (Lowenstine, McManamon and Terio, 2016). Anecdotal evidence indicates that all bonobos in American Zoo Association collections are on some sort of cardiovascular medication (N. Lung, personal communication, 2020). If that is the case, is it due to misdiagnosis? Or is something in ex-situ environments causing captive apes to suffer from similar organ issues to humans?

Analysis of cardiac disease in apes often uses inferences based on data from their closest genetic relatives—humans. The Great Ape Heart Project was formally established in 2010 to study and understand cardiac disease in great apes in captivity, using data from American Zoo Association collections (Detroit Zoological Society, n.d.). The International Primate Heart Project (IPHP) followed in 2012, with the aim of creating improved understanding of cardiac disease in great apes, initially as a collaboration between veterinary practitioners, cardiac physiologists and cardiologists (Cardiff Metropolitan University, n.d.). In 2016, the Ape Heart Project was launched by Twycross Zoo, the University of Nottingham and the University of Birmingham to "develop a collaborative and co-operative approach to the investigation of heart diseases among the European great ape population" (BBC, 2016; Twycross Zoo, n.d.).

The IPHP methodology highlights consistency of data gathering—using a multidisciplinary team of cardiologists, echocardiographers, physiologists and veterinarians, who travel internationally to gather consistent, and therefore comparable, cardiac data and provide bespoke training to field practitioners. The team's first publication was a how-to guide on conducting a cardiac assessment (Shave *et al*., 2014). IPHP postulates that veterinary professionals may be better able to diagnose, treat and manage captive great apes with, or at risk of developing, heart disease by applying a thorough, systematic "animal in the environment" approach, rather than treating the cardiovascular system as a separate entity.

Given widespread data deficiencies, it is common across the wildlife veterinary profession to use "similar" species' clinical values as a proxy for species on which information is limited. IPHP results suggest that this proxy approach is not ideal for cardiovascular disease. The project encourages professionals to use a comprehensive approach to cardiac assessments—one that employs various ultrasound modalities to provide a thorough description of overall cardiac structure and function, which can then be used to inform clinical opinion (Shave *et al*., 2014). IPHP data indicate that translational medicine approaches could have profound impacts on both the welfare and conservation management of captive apes as well as wild populations. Evidence for this position is growing, supported by the IPHP network's scientific studies on ape cardiovascular health, cardiac structure and function, and electrocardiogram assessments (Curry *et al*., 2023; Drane *et al*., 2019, 2020).

This work could have far-reaching implications for medical research. If consensus is reached that the human being is not a good model for ape cardiac health, questions may similarly be raised with respect to the widespread use of domestic species as physiological models for the health of wildlife species. Moreover, in addition to improving decision-making processes in apes' and other animals' cardiac health, this understanding and use of translational medicine could inform the evolution of and approach to cardiovascular disease in humans themselves (Drane *et al*., 2019, 2020).

CASE STUDY 2.7

The Borneo Nature Foundation: Ecosystem Conservation and One Health

Theme: Integrating the One Health approach into ecosystem conservation.

Applicable Berlin Principles:

- ☑ 1. Conservation
- ☑ 2. Strong institutions
- ☑ 3. Climate crisis
- ☑ 4. Ecosystems
- ☐ 5. Disease control
- ☐ 6. Biodiversity integration
- ☑ 7. Investment
- ☐ 8. Enhanced capacity
- ☐ 9. Multilevel collaboration
- ☑ 10. Awareness raising

Disciplines relevant to One Health: Ecology, disaster preparedness, community development, capacity building

The Borneo Nature Foundation and One Health

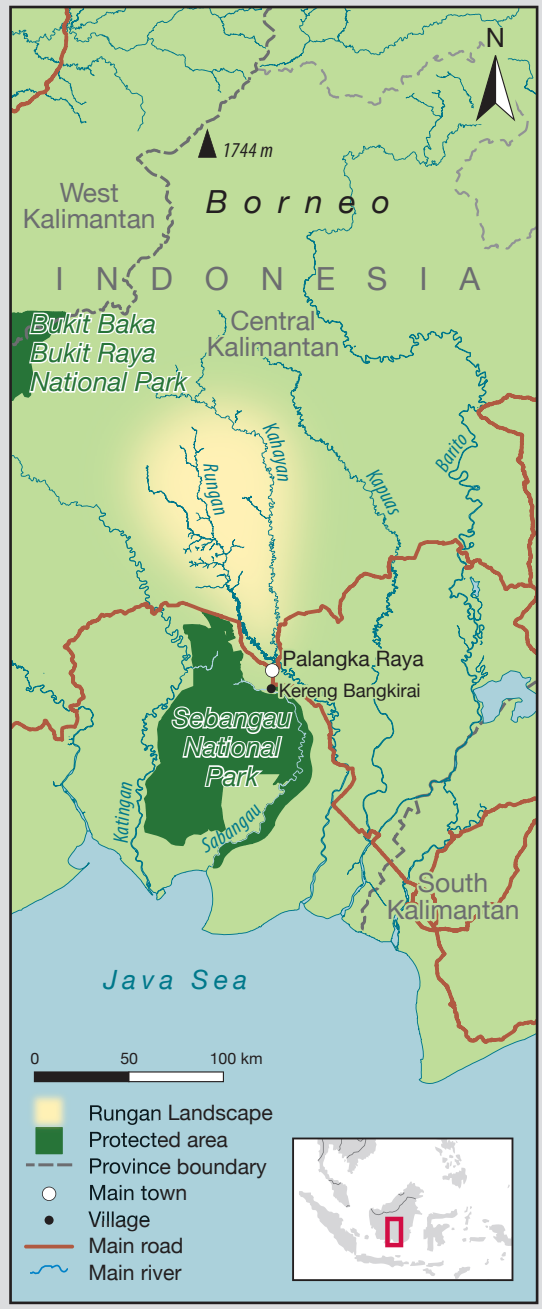
Apes have a role to play in maintaining a healthy ecosystem. Borneo Nature Foundation (BNF) is a non-profit wildlife and biodiversity conservation and research organization that protects and safeguards tropical rainforests and the environment in Borneo (see Figure 2.7). BNF collaborates with the Central Kalimantan Department of Environmental Services, the provincial division of the Indonesian Ministry of Environment and Forestry, and with the Sebangau National Park authorities. As a landscape conservation-focused organization, BNF has successfully merged ape population health surveillance with landscape conservation goals. Data gaps remain, particularly regarding disease investigation within the system, but the research infrastructure is already in place to include that target in future operations.

BNF's research-focused, iterative approach has provided a robust framework for tackling future One Health concerns in the region (BNF, n.d.-d). Compared to great ape research, the study of wild gibbons is particularly difficult due to the speed with which they move through the canopy and the difficulty of habituating them. These factors render disease surveillance in the field challenging. Nevertheless, BNF is the only project to have more than seven years' worth of accumulated data on the behavior, health and wellbeing of wild, individually identified animals in three populations, which provides useful ecological and health data as a foundation for One Health-focused research and messaging (S. Cheyne, personal communication, 2021).

Recent publications from the BNF research team and collaborators reveal the importance of incorporating the social sciences into orangutan conservation (Chua *et al.*, 2020; Palmer, 2020; Sherman *et al.*, 2021). These studies explored the hypothesis that greater conservation benefits could be achieved if ape practitioners deliberately and consciously reduced the pace of decision-making in the face of environmental crises (real and potential) and thought more reflexively and creatively about how the work they do can be improved (Chua *et al.*,

FIGURE 2.7

Borneo Nature Foundation Work Area



Sources: Protected areas—UNEP-WCMC (2021d); country boundaries—GADM (n.d.); other base map detail—OpenStreetMap (n.d., © OpenStreetMap contributors, published under Creative Commons Attribution License CC BY; for more information see http://creativecommons.org)

2020). This openness to changing their paradigm and improving preparedness can produce more impactful responses.

BNF's Use of a Systems Approach to One Health Challenges

BNF's projects integrate wildlife, landscape and Indigenous culture via community-led initiatives. These include monitoring the distribution, population status, behavior and ecology of both the Bornean orangutan (*Pongo pygmaeus*) and Bornean gibbons (*Hylobates funereus* and *Hylobates albibarbis*) (BNF, n.d.-d). The systems approach allows BNF to target the drivers of ape population decline and disease in the area. It also enhances the local human population's understanding of their contribution to maintaining healthy primate populations—in terms of the size of the population, its genetic potential and protection against disease. As discussed below, the approach include projects focused on fire prevention, youth, social forestry schemes, community engagement, and orangutan and gibbon health.

Preventing Forest Fires: Peatland Protection and Restoration in Sebangau National Park

Whereas BNF previously ran a program on reacting to forest fires, today its focus is on prevention—a central tenet of One Health practice (BNF, n.d.-c). This initiative involves:

- forest restoration, particularly in the area bordering the major city of Palangka Raya;
- community patrol teams whose aim is to prevent illegal logging, illegal hunting and electric fishing;
- community-based fire-prevention units that patrol and extinguish any identified fires;
- the detection, mapping, reporting and blocking of illegally built drainage channels, which dry out the peatland forest and make the area more susceptible to fire; and
- new technologies, including handheld data collection devices; aerial drones fitted with thermal imagery software to spot and map fires; and automated data loggers to collect hydrological data (see Chapter 6).

All of these activities are coordinated with the Sebangau National Park Authority, the regional Disaster Management Agency and the Peatland Restoration Agency to ensure an integrated, collaborative approach, which supports a network of fire-fighting teams.

Connecting Young People to Nature

The Sebangau research camp, managed by BNF partners at the University of Palangka Raya, is located on the edge of the forest. Less than an hour from the city center, the camp includes a network of forest trails and an environment rich in wildlife. The camp allows young people to experience the rainforest and learn to care for and protect it. One aspect of this initiative is the Gibbon Goes to School education program for 6–8-year-olds.

Social Forestry Schemes and Habitat Protection through Industry Engagement

The Rungan River Landscape contains 1,474 km^2 (147,357 hectares) of forest, a significant proportion of which is in industrial tree concessions, with between 2,220 and 3,275 orangutans living in a mosaic of habitats (Ancrenaz *et al.*, 2021; Jong, 2022). The landscape represents one of the largest unprotected areas of forest in the Bornean lowlands and is critically important not only for biodiversity conservation, but also for supporting the livelihoods of Indigenous Dayak people (Liswanti *et al.*, 2004). To protect this forest, BNF is working together with government partners to promote the expansion of a local social forestry initiative, through which villages can claim management rights over their forest, to ensure its protection as a village resource for the future (S. Cheyne, personal communication, 2021).

Community Engagement

Having identified that wider community engagement was urgently needed, BNF prioritized the construction of a new education and conservation hub in 2020–2021 (BNF, n.d.-e). The hub supports all community projects in the village of Kereng Bangkerai, the gateway to the Sebangau National Park, including:

- community-based fire-prevention units;
- children's education activities;
- research teams engaged in data processing and the writing of reports; and
- the Sebangau National Park Authority, which plans to construct a visitor's center to showcase the park to visitors.

Promoting Healthy Populations of Orangutans and Gibbons

Aerial surveys of orangutans. BNF was founded by scientists studying the density and distribution of orangutans and collecting field-based nest data (BNF, n.d.-a). Plans are in development to supplement field-based data collection with drone-based surveys, to increase both the scale and efficiency of BNF's surveys. In partnership with Liverpool John Moores University, researchers are planning to use drones to locate nests and attempt to locate apes in the forest using thermal imaging cameras (BNF, n.d.-b).

Assessing the status of key endangered species in Kalimantan. In addition to studying orangutans, BNF's scientists observe many other endangered species in Kalimantan. These include gibbons, wild cats, birds and sun bears (*Helarctos malayanus*). In 2020, they also began to conduct riverine surveys of crocodilians and proboscis monkeys (*Nasalis larvatus*). Their aim is to improve ecosystem health by presenting information on important hotbeds of biodiversity and encouraging a rounded approach to biodiversity conservation in Central and West Kalimantan.

clear or singular solutions to some problems (Bennett *et al.*, 2017; Game *et al.*, 2014). A case in point is the Borneo Nature Foundation, a conservation project whose approach integrates consideration of the human impact on ape health (see Case Study 2.7).

Conclusion

The concept of One Health has matured since the term was first used around 2003 (Mackenzie and Jeggo, 2019). Today it is acknowledged as a way of thinking about, approaching and solving ecosystem-level health problems. The case studies presented in this chapter—and their links to the Berlin Principles of One Health—illustrate the breadth of ape conservation endeavors that take a One Health approach. Nevertheless, there is a need for supporting data and evaluation of this approach in ape-specific situations going forward.

The threats to apes, ape habitats and ape health are cross-sectoral and multifaceted—hence the need for collaborative and interdisciplinary solutions. The One Health approach has traditionally been driven from

the animal health perspective, but the process of considering and designing ape conservation programs requires expertise from a wide range of disciplines. The solutions are many, varied and complex, and they may be implemented at an individual or population level. They also come in a variety of forms, including specific individual treatments translated from human internal medicine; community-level changes to land management; and regional, national and international policy interventions. Since ape survival is inextricably linked to human development, best practice is to factor consideration of the SDGs into any One Health approach to ape wellbeing. The key elements for success are capacity, collaboration, resources and motivation.

Acknowledgments

Principal authors: Steve Unwin,[8] Dominic Travis,[9] Thomas Gillespie[10] and Elizabeth Cook[11]

Contributors: Lynne Gaffikin,[12] Gladys Kalema-Zikusoka,[13] Citra Nente[14] and Benard Ssebide[15]

Box 2.1: Steve Unwin

Box 2.2: Steve Unwin

Box 2.3: Dominic Travis

Case Study 2.1: Gladys Kalema-Zikusoka

Case Study 2.2: Citra Nente and Benard Ssebide

Case Study 2.3: Steve Unwin

Case study 2.4: Elizabeth Cook

Case studies 2.5–2.7: Steve Unwin

Endnotes

1 From a presentation at the XXI Congress of the International Primatological Society, Entebbe, Uganda, June 25–30, 2006 and noted by D. Travis.

2 The concept of community has expanded to include like-minded groups, communities of practice and others that may communicate virtually (MacQueen *et al.*, 2001).

3 These approaches have been referred to as "whole-of-society" efforts (Warren *et al.*, 2021).

4 Unless otherwise cited, material in Case Study 2.1 is based on the author's extensive knowledge of this situation, as founder and leader of CTPH and as a veterinarian whose work has contributed to ape health in Uganda since 1996.

5 Unless otherwise cited, the material presented in Case Study 2.2 is based on the authors' extensive knowledge of these situations. Citra Nente has been head of ex-situ conservation for YEL since 2017; prior to that, she was a veterinary clinician at the Borneo Orangutan Survival Foundation for 20 years. Benard Ssebide has worked for Gorilla Doctors as a Uganda-based clinician and manager for almost 15 years.

6 Deere *et al.* (2019); Grützmacher *et al.* (2018b); Köndgen *et al.* (2008); Negrey *et al.* (2019); Palacios *et al.* (2011); Parsons *et al.* (2015); Rwego *et al.* (2008); Scully *et al.* (2018).

7 Pilot research was conducted by Steve Unwin (at the time: University of Birmingham) and Yenny Saraswati (Sumatran Orangutan Conservation Programme), with funding from both the University of Birmingham and the Primate Microbiome Project.

8 University of Birmingham (https://www.birmingham.ac.uk/schools/biosciences/index.aspx) then Wildlife Health Australia (https://wildlifehealthaustralia.com.au).

9 University of Minnesota (https://vetmed.umn.edu).

10 Emory University (http://envs.emory.edu/home/index.html).

11 Consultative Group on International Agricultural Research (https://www.cgiar.org).

12 Stanford University (https://www.stanford.edu).

13 Conservation through Public Health (https://ctph.org).

14 Sumatran Orangutan Conservation Programme (https://www.sumatranorangutan.org).

15 Gorilla Doctors (https://www.gorilladoctors.org).

Photo: Buffer zones are areas of controlled resource extraction around protected areas. They provide benefits to local communities while reducing pressures associated with human encroachment on wild spaces. Village on the edge of Gunung Palung National Park, Indonesia. © Alison White