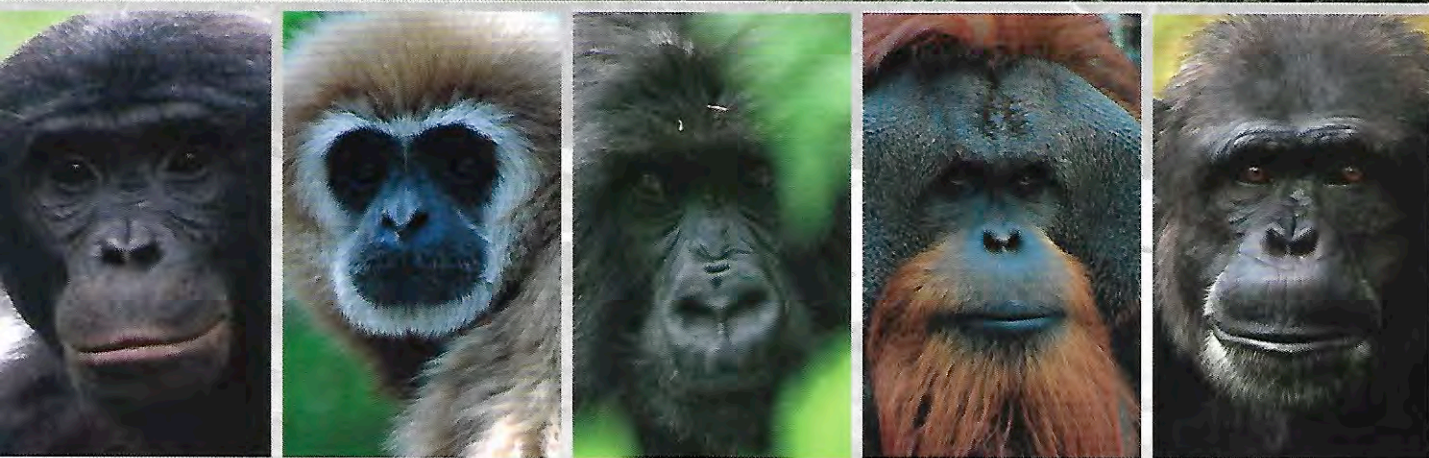


# State of the Apes

## Infrastructure Development and Ape Conservation



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Ape Conservation



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## CHAPTER 4



### Apes, Protected Areas and Infrastructure in Africa

#### Introduction

Equatorial Africa sustains the continent's highest levels of biodiversity, especially in the wet and humid tropical forests that harbor Africa's apes. This equatorial region, like much of sub-Saharan Africa, is facing dramatic changes in the extent, number and environmental impact of large-scale infrastructure projects. A key concern is how such projects and the broader land use changes they promote will affect protected areas—a cornerstone of wildlife conservation efforts.

This chapter assesses the potential impact of new and planned infrastructure projects on protected areas in tropical Africa, particularly those harboring critical ape habitats. It focuses on Africa not because tropical Asia is any less important, but because analyses

of comparable detail are available only for certain parts of the Asian tropics (Clements *et al.*, 2014; Meijaard and Wich, 2014; Wich *et al.*, 2016). Such knowledge gaps underscore the importance of future work on infrastructure impacts in Asia.

Ape range states in tropical Africa are encountering an array of important changes. These include an unprecedented expansion of industrial mining (Edwards *et al.*, 2014); more than 50,000 km of proposed “development corridors” that would crisscross much of the continent (Laurance *et al.*, 2015b; Weng *et al.*, 2013); the world’s largest hydro-power dam complex (International Rivers, n.d.-c); ambitious plans to expand industrial and smallholder agriculture (AgDevCo, n.d.; Laurance, Sayer and Cassman, 2014b); extensive industrial logging (Kleinschroth *et al.*, 2016; LaPorte *et al.*, 2007); and myriad other energy, irrigation and urban infrastructure projects (Seto, Güneralp and Hutya, 2012).

Many of the largest infrastructure projects in Africa are being advocated because of concerns about the continent’s booming population, which is expected to nearly quadruple this century (UN Population Division, 2017). This projection is creating apprehension about food security and human development, and broader anxieties about the potential for social and political instability (AgDevCo, n.d.; Weng *et al.*, 2013). Africa faces serious challenges revolving around:

1. effective design and assessments of new infrastructure projects to limit their environmental and social impacts;
2. good governance for nations experiencing unprecedented foreign investments for infrastructure and natural resource extraction; and
3. management of economic instabilities that can plague nations largely reliant on just a few natural resources or commodities for export income (see Chapter 1).

## Key Findings

The main findings of this chapter are:

- Africa is experiencing an unprecedented proliferation of infrastructure projects and, consequently, dramatic changes in land use, the effects of which are likely to have an impact on many protected areas in critical ape habitats and beyond.
- Advances in remote sensing, computing power and databases are rapidly improving the quality and accessibility of information on the distribution of roads and other infrastructure, as well as on the attributes and threats affecting global protected areas.
- Foreign investment, in extractive industries in particular, is playing a key role in promoting infrastructure expansion in Africa.
- Protected areas in Africa are particularly vulnerable to reductions in size or downgrading of their protection status if they hinder exploitation of natural resources or limit infrastructure expansion.
- Growing pressures from infrastructure expansion and land use changes in the regions immediately surrounding protected areas can have adverse effects on ecological integrity, biodiversity and functional connectivity. Larger parks are generally less susceptible to such external pressures.
- While roads inside parks may foster ecotourism, the best way to limit the impact of human disturbance on sensitive wildlife and ecological processes is to ensure that core areas of parks remain road-free.
- There is an urgent need to implement considered land use and infrastructure planning, and to apply the “mitigation hierarchy” to avoid, minimize, restore and offset threats to endangered apes and other iconic species and critical habitats in equatorial Africa.

## African Ape Ranges and Protected Areas

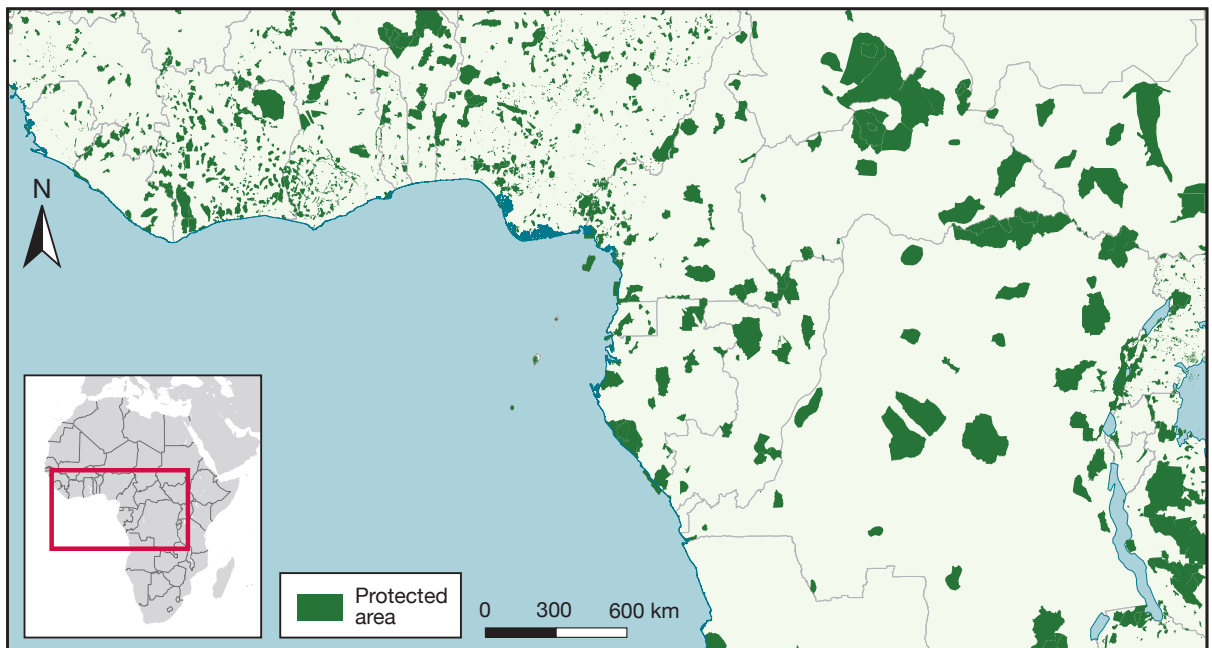
In Africa, several factors complicate efforts to conserve viable species and subspecies of apes. One concerns the limited geographic ranges of many apes (see the Apes Overview and Figures AO1 and AO2). Another is the imprecision of published range maps, which typically overestimate ape distributions, reflecting the fact that most species are patchily distributed as a result of natural habitat variability and spatially varying human pressures. When such patchiness is taken into account, many wildlife species are in fact more seriously imperiled than suggested by the International Union for Conservation of Nature (IUCN) Red List classifications (Ocampo-Peñuela *et al.*, 2016). Political conflicts, remoteness and limited scientific resources further hinder efforts to identify key threats and monitor ape populations.

Where reasonably robust data have been gathered, at least some ape taxa have been shown to suffer serious population declines. In the eastern Democratic Republic of Congo (DRC), for example, field surveys suggest that the critically endangered Grauer's gorilla (*Gorilla beringei graueri*), a locally endemic subspecies, has declined by 77% to 93% in abundance over the past two decades (Plumptre *et al.*, 2015).

Although more than 6,400 protected areas occur across sub-Saharan Africa, only a limited number are considered “large”—meaning that few cover more than 10,000 km<sup>2</sup> (1 million ha)—especially in the continent's equatorial regions that harbor ape populations (Laurance, 2005; Sloan, Bertzky and Laurance, 2016). In West and Central Africa, protected areas broadly coincide with ape ranges (see Figure 4.1 and Figure AO1). African apes are represented by five species and a number of restricted subspecies. They

**FIGURE 4.1**

Protected Areas in West and Central Africa



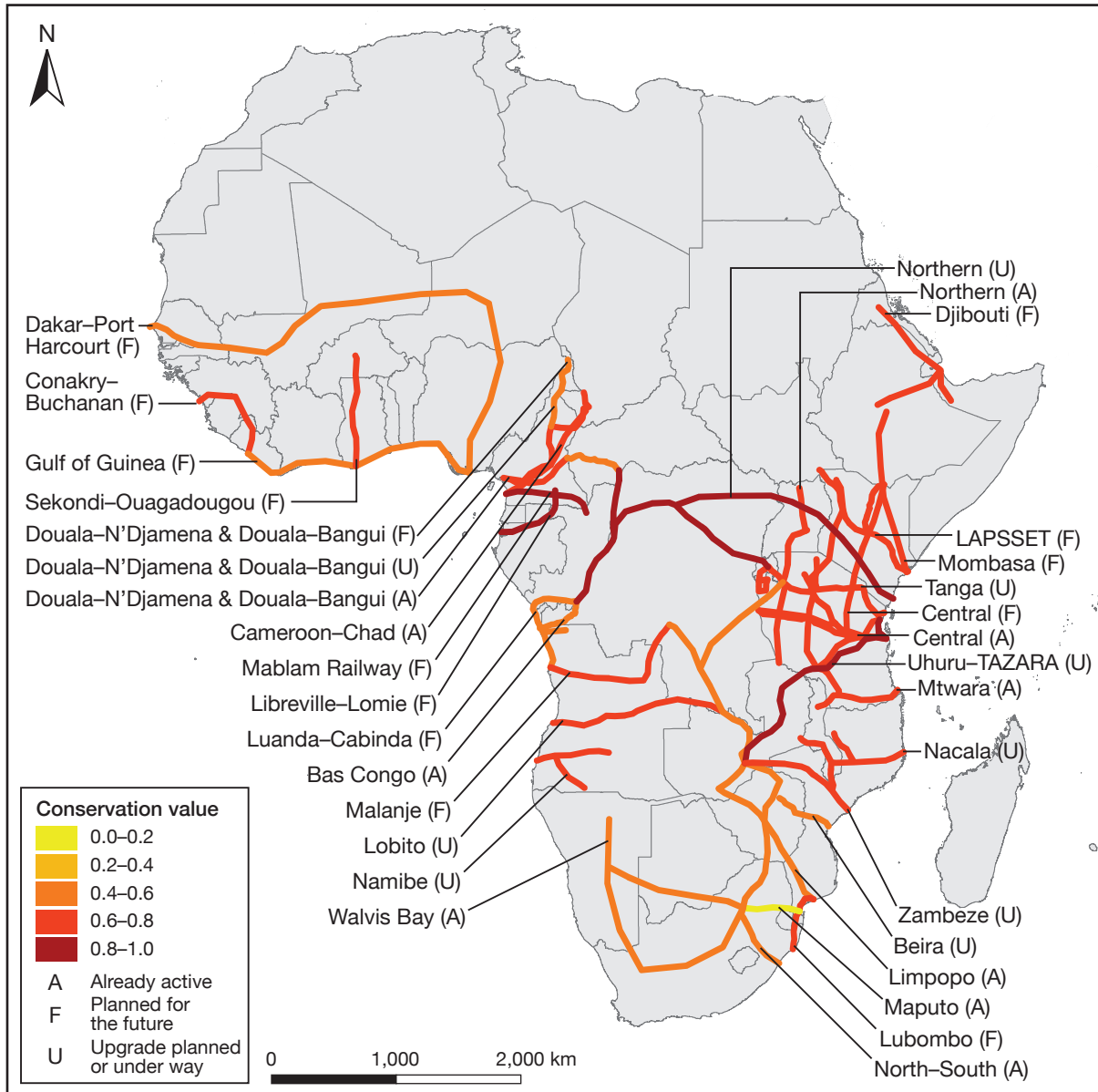
Data source: UNEP-WCMC and IUCN (n.d.)

are separated by geographic features such as the arid Dahomey Gap, which splits the West African rainforests and the extensive rainforests of Central Africa; major rivers,

such as the Congo, which separates bonobos from other African apes; and two tall massifs that sustain populations of mountain gorillas (*Gorilla beringei beringei*).

**FIGURE 4.2**

**Conservation Values of Habitats within 25 km of 33 Development Corridors in Sub-Saharan Africa**



**Notes:** Conservation values are estimated based on biodiversity, threatened species, critical ecosystems, wilderness attributes, environmental services and human population densities of habitats within a 25 km buffer zone around 33 proposed or existing development corridors. Values are shown on a relative scale, from 0 (low conservation value) to 1 (high conservation value).

**Data source:** Laurance *et al.* (2015b)



## Threats to Protected Areas from Infrastructure

### Africa's "Development Corridors"

A true game-changer for African nature conservation is the proposed and ongoing construction of at least 35 development corridors. If completed in their entirety, the corridors will crisscross sub-Saharan Africa, spanning a length of more than 53,000 km in total (Laurance *et al.*, 2015b).

These corridors are likely to affect existing nature reserves in at least three ways:

- First, by bisecting reserves, fragmenting them and opening them up to illegal encroachment and poaching (Sloan *et al.*, 2016).
- Second, by promoting colonization, habitat loss and intensified land use around reserves, they could decrease the ecological connectivity of the reserves to other nearby habitats.
- Third, environmental changes in the lands immediately surrounding a nature reserve tend to infiltrate inside the reserve itself (Laurance *et al.*, 2012). To some degree, a reserve with extensive logging and hunting in its surrounding lands will be exposed to those same threats within its own borders.

A detailed analysis of 33 of the proposed and ongoing development corridors<sup>1</sup> indicates that:

- many corridors would occur in areas that have high conservation value and are only sparsely populated by people (see Figure 4.2);
- the corridors would bisect more than 400 existing nature reserves; and
- assuming that land use changes intensify within 25 km on either side of each

corridor, more than 1,800 reserves could experience deterioration in their ecological integrity and connectivity, as well as additional human encroachment (Laurance *et al.*, 2015b).

In total, the 33 development corridors could bisect or degrade more than one-third of all existing protected areas in sub-Saharan Africa (Laurance *et al.*, 2015b). The 23 corridors that are still in the planning or initial upgrading phases would be especially dangerous for nature. These corridors would bisect a larger proportion of high-priority reserves—such as World Heritage sites, Ramsar wetlands and UNESCO Man and Biosphere Reserves—than would existing development corridors. Collectively, the 23 planned corridors would slice through more than 3,600 km of reserve habitat (Sloan *et al.*, 2016).

Of the approximately 2,200 African protected areas that could be affected by development corridors, a number include ape range habitats. For example, two epicenters of bisected reserves—the iron-rich belt spanning southern Cameroon and the northern Republic of Congo, and the Great Lakes region of East Africa (see Figure 4.2)—harbor vital ape habitats (Sloan *et al.*, 2016). There would also be considerable losses of important habitats outside of protected areas. A simulation model developed by the World Bank projects that in the Congo Basin, which is critical habitat for apes, expanding roads and transportation infrastructure will be the biggest driver of deforestation through 2030 (Megevand, 2013).

### The Grand Inga Hydroelectric Project, DRC

While it is not possible here to describe the full range of infrastructure projects that could diminish African ape habitats, one cannot fail to mention the massive hydro-

electric project under construction near Inga Falls on the lower Congo River. Should it proceed as planned, the Grand Inga dams will generate more electricity—40,000 megawatts (MW)—than any other single project on Earth. To achieve this level of output, however, the project will inundate more than 22,000 km<sup>2</sup> (2.2 million ha) of largely forested lands in the western DRC (Abernethy, Maisels and White, 2016). Dam projects in tropical regions often have deforestation footprints that markedly exceed the flooded reservoir itself, because road networks needed for dam and power line construction also provoke major forest disruption (Barreto *et al.*, 2014; Laurance, Goosem and Laurance, 2009; see Chapter 6).

## Road Proliferation

One of the most serious effects of large-scale infrastructure projects—be they hydroelectric dams, mines, development corridors or nearly any other large development scheme—is that they provide a strong economic impetus for road building. Since they can open a Pandora's box of hunting, land colonization and other human activities, such roads often pose a greater threat to ecosystems and biodiversity than the original infrastructure project itself (Laurance *et al.*, 2015a). Moreover, many roads are constructed illegally; consequently, they do not appear on official road maps.

Hence, one of the most fundamental challenges facing those who seek to manage land use activities and limit their threat to nature is simply determining the locations of existing roads. The number of illegal and unmapped roads is generally much greater in developing nations, such as those that sustain ape populations, than in wealthier industrial nations (Ibisch *et al.*, 2016). For this reason, simply mapping existing roads is a major priority, one that is beset by some important technical challenges (see Box 4.1).

### BOX 4.1

#### The Challenge of Mapping Roads

##### Key Uncertainties

A common misperception is that roads and other transportation infrastructure have been adequately mapped at the global scale, and that related data are readily available. In fact, they are not, and this lack of information creates serious challenges for nature conservation.

Road maps suffer from two key sources of uncertainty. First, the quality of road maps differs markedly across nations. In Switzerland, for instance, nearly every viable road is mapped, whereas in developing nations such as Indonesia or Nigeria, road maps are far from complete. Second, developing nations in particular have many illegal or unofficial roads that do not appear on any map. In the Brazilian Amazon, for example, a recent analysis found nearly three kilometers of illegal, unmapped roads for every kilometer of mapped, legal road; further, 95% of all deforestation occurred within 5.5 km of a legal or illegal road (Barber *et al.*, 2014). Since roads play such a dominant role in determining the pattern and pace of habitat disruption, it is vital to have a clear sense of where roads and other transportation infrastructure are located (Barber *et al.*, 2014; Laurance *et al.*, 2001, 2009).

For information on roads, the best freely available global data set is gROADS, the Global Roads Open Access Data Set, although it suffers from notable differences in accuracy and temporal coverage across nations (CIESIN and ITOS, 2013; Ibisch *et al.*, 2016; Laurance *et al.*, 2014a). gROADS staff manually digitized coarse-scale (1:1,000,000) hardcopy maps, often from the 1980s and 1990s. This process resulted in horizontal-accuracy limitations ( $\pm 2$  km) that restrict the use of gROADS to general comparisons, especially within, rather than across, nations.

##### Information Revolution

The late 1990s saw rapid growth in road mapping, driven by the rise of the in-car navigation industry. Often restricted to specific navigation devices and applications, the widespread use of global road data



was revolutionized in 2005 with the launch of Google Maps ([maps.google.com](http://maps.google.com)) and continued with subsequent data collection campaigns. These developments have generated detailed coverage for urban roads worldwide, although data for rural areas are much more patchy. Google Maps data have commercial applications (linked to advertising and location-based search results); their use for nonprofit websites and independent data analysis is thus restricted.

Despite their proprietary nature, Google Maps data are being used to help generate the Global Roadless Areas Map, a collaboration among Google, the Society for Conservation Biology and the European Parliament. This initiative began in 2012 under the aegis of RoadFree ([www.roadfree.org](http://www.roadfree.org)), an initiative designed to highlight the importance of roadless wilderness areas for biodiversity conservation and the reduction of atmospheric carbon emissions. RoadFree has helped to spur interest in improving maps of transportation infrastructure, using a variety of data sources and techniques.

In parallel with commercial road data, an initiative known as OpenStreetMap (OSM) ([www.openstreetmap.org](http://www.openstreetmap.org)) has grown dramatically. OSM aims to create a free and editable map of the world. Since its launch in 2004, it has grown into a community of more than 4 million registered members, around 2,000 of whom are making daily edits. Between late 2016 and mid-2017, the number of road features in the OSM database

increased impressively from 376 million to 430 million, in addition to many other features, such as buildings.

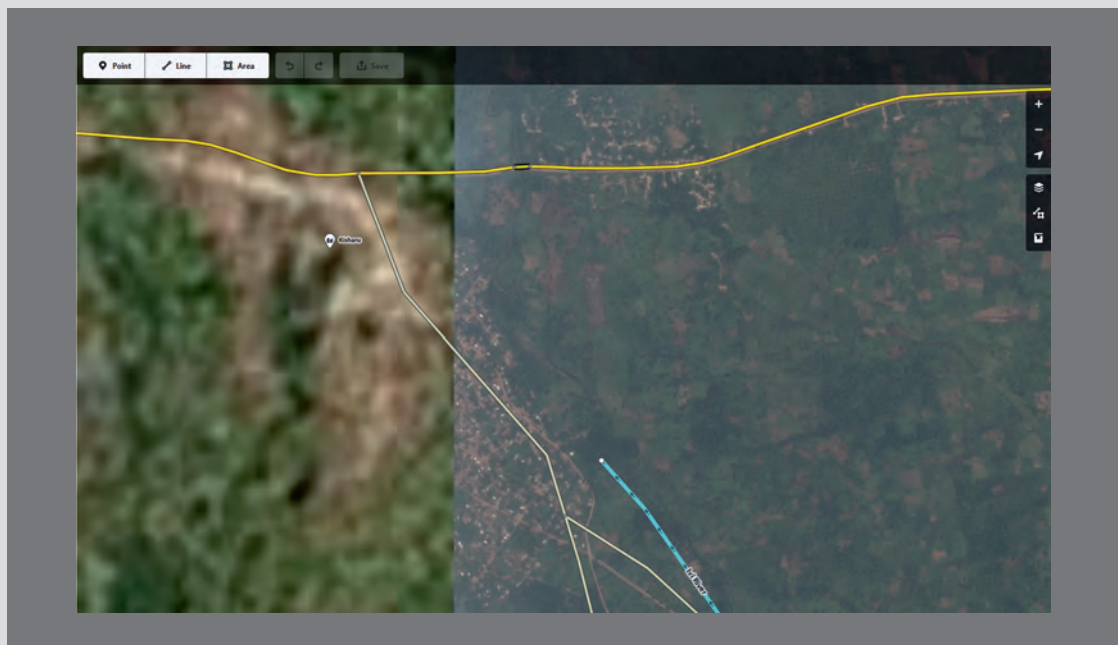
Efforts are underway to focus OSM development on evolving environmental crises and to improve data for areas that are inadequately mapped. Notable among these are two programs aimed at mapping roads in tropical forests. The first, Roadless Forest ([roadlessforest.eu](http://roadlessforest.eu)), is a European Union initiative to assess the benefits of road-free forests, strongly linked to EU policies on reducing illegal logging and carbon emissions from forest disruption (FLEGT, 2016; REDD+, n.d.). The second is Logging Roads ([loggingroads.org](http://loggingroads.org)), which focuses on mapping logging roads in the Congo Basin. The good news is that all mapping improvements from these various initiatives are being placed immediately on the publicly available OSM database. An OSM Analytics platform ([osm-analytics.org](http://osm-analytics.org)), released in 2016, enables tracking of this mapping activity for roads and buildings at the global level.

#### Technical Challenges and Advances

While the new road mapping initiatives are invaluable, many technical challenges remain (Laurance *et al.*, 2016). For instance, the spatial resolution of available imagery can differ greatly across particular areas of interest, compromising efforts to create accurate and comparable infrastructure maps. Figure 4.3 illustrates that spatial resolution can vary across

**FIGURE 4.3**

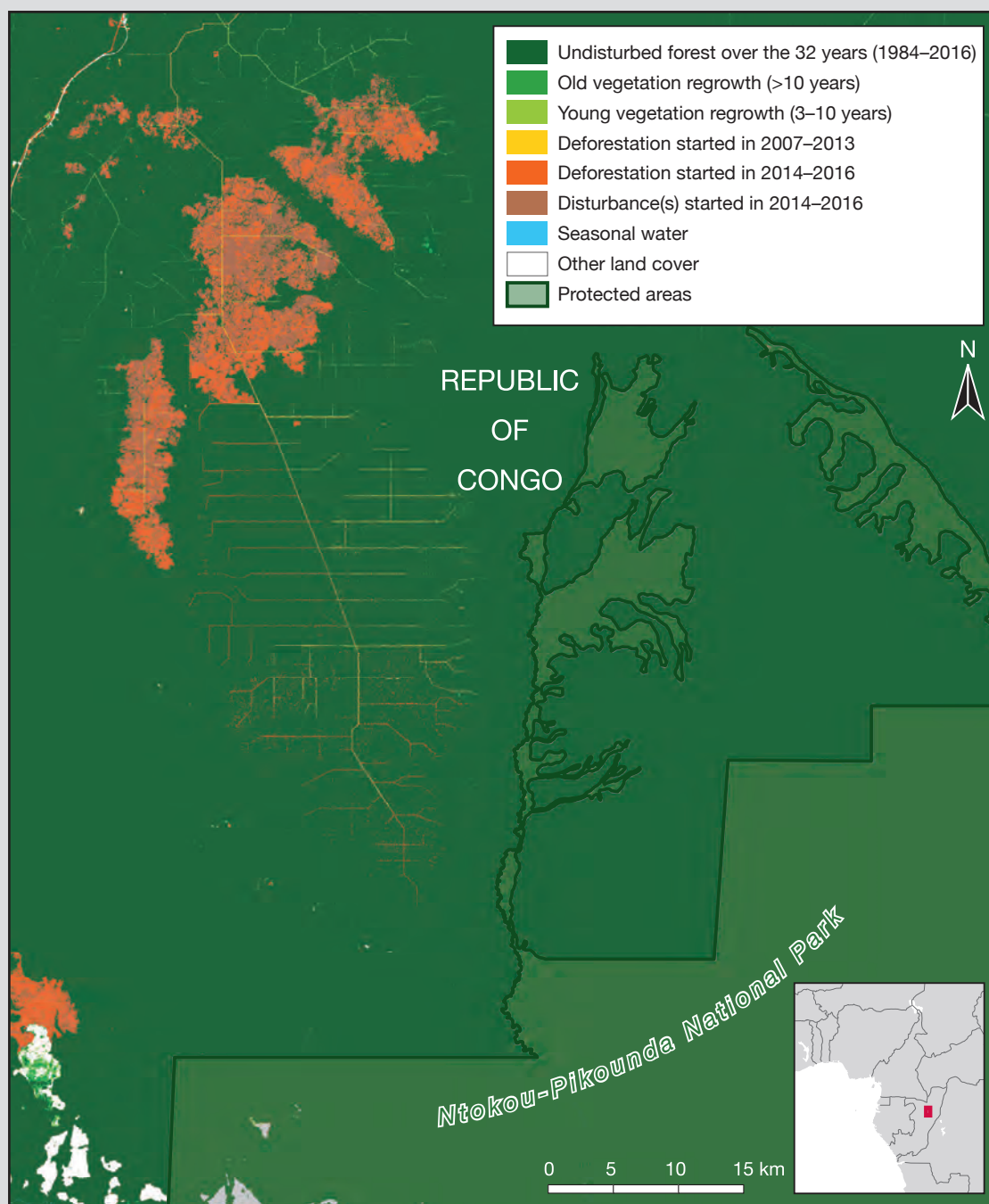
Mapping Discrepancies in an Area of Rutshuru Reserve, Uganda, in OpenStreetMap



Source: © OpenStreetMap contributors – [www.openstreetmap.org](http://www.openstreetmap.org)

**FIGURE 4.4**

Recent and Ongoing Logging-Road Activity in the Congo Basin, near Ntokou-Pikounda National Park, as Identified by Time-Series Analyses of Landsat Imagery



Source: Vancutsem and Achard (2016)



images; it also shows inaccurate road positions derived from older coarse-scale maps.

A common assumption is that increasingly higher-resolution satellite imagery is needed for better road mapping. However, spatial data from the Landsat and EU Sentinel satellites, and composite images produced by Google Earth, all have reasonably high resolution, sufficient for many road-mapping applications. Furthermore, with each satellite pass, higher-resolution sensors cover a narrower swath of land than do lower-resolution ones, and therefore they return to the same area less frequently. This slow return time can be a major constraint in the effort to find cloud-free images in the wet tropical regions that are key ape habitats. Fine-scale imagery (<1 m resolution) exists but is expensive, requires massive data storage capacity and is rarely available for the remote environments inhabited by apes. Finally, the long time period over which Landsat imagery has been available allows changes in land use and roads to be observed for intervals of up to several decades (given that Landsat commenced in 1972 and Landsat Thematic Mapper, with 30-m resolution sufficient for detecting roads in dense forests, began in 1982). This long-term coverage is extremely valuable for assessing the spatial patterns and drivers of land use change over time. Until recently, high data costs, inadequate computing power and limited access to imagery precluded the systematic processing of remotely sensed data over periods exceeding 30 years. Prior to 2008, all Landsat data were provided on a commercial basis; as a result, the use of the data was meager. Once the data were made freely available, their use skyrocketed. This has fuelled numerous innovations, of which Google Earth Engine is perhaps the most notable. Launched in 2010, it has allowed global-scale analyses using the power of Google's own cloud-computing infrastructure.

With pricing and technical barriers for data and computing falling dramatically, opportunities for global-scale environmental analysis have grown rapidly. For example, researchers at the European Commission's Joint Research Centre have developed techniques to identify forest disturbances at a resolution of 30 m × 30 m as far back as 1982, using Google Earth Engine as the processing platform (Vancutsem and Achard, 2016; see Figure 4.4). Similarly, the rapid repeat time of Landsat has allowed researchers to find enough cloud-free images to effectively monitor the expansion of tropical logging roads. This technique can be used to highlight areas susceptible to road expansion and forest change (see Chapter 7), which in turn can feed into community-mapping programs such as OSM. The next step is to attempt to predict the environmental impacts of different road development scenarios on forests (Laurance *et al.*, 2001).

#### **Needed: Road-Detection Algorithm**

For all the sophistication of modern remote-sensing technologies, researchers still lack an automated computer algorithm that can reliably detect and map roads under the hugely

varying range of topographic, land use, sun-angle and road-surface conditions that one encounters in the real world. For this reason, actual road mapping is usually done with human eyes—by using the best available satellite imagery and manually tracing roads with a mouse onto a computer screen. Known as “armchair mapping,” this method is still the most effective for mapping roads and determining whether they are paved or unpaved. Unfortunately, this is a very time-intensive process. Even with hundreds of active mappers, several years would be required to map all the roads on the planet. By the time the mappers had finished mapping Earth's roads, it would be necessary to start anew to identify the many new roads that would have been created since the project began. For such reasons, a holy grail for those studying roads is an automated system that can detect and map roads accurately in near-real time (Laurance *et al.*, 2016).

#### **Forest Monitoring**

As a result of vastly improved data accessibility and computing power, forest monitoring by satellites has advanced impressively. In 2014, Global Forest Watch announced a revamped website ([www.globalforestwatch.org](http://www.globalforestwatch.org)), powered largely by Landsat satellite data (see Chapter 7). The next generation of Earth-observation satellites—the Sentinel-2 series from the European Space Agency—will have even higher spatial resolution (10 m), better spectral data (red, green, blue, near infrared), and faster return times (5 days) than does Landsat. The image characteristics of the Sentinel satellites will lend themselves to forest- and road-mapping applications (Verhegghen *et al.*, 2016). The fact that their data are entirely free and open access should help to stimulate further innovations.

#### **Next Steps**

Finally, there is a need to go beyond simple maps of transportation infrastructure and look more broadly at accessibility. The World Bank and European Commission produced a Global Accessibility Map that estimates the travel time from any point on Earth to the nearest city exceeding 50,000 people (Nelson, 2008). Although focused on access to urban services, the map highlights the limited and shrinking extent of wilderness worldwide (Ibisch *et al.*, 2016; Laurance *et al.*, 2014a; Watson *et al.*, 2016). With more and better roads, advances in vehicle technology and a rapid increase in the number of motorized vehicles, the globe is shrinking fast. Already, just one-tenth of the world's land surface is more than 48 hours' travel time from a major city (Nelson, 2008). Clearly, this is leading to increased pressure on ecosystems and biodiversity.

There is both enormous potential and an urgent need to devise better road-mapping tools, and to use these to assess road-related pressures to ape habitats. A logical next step is to identify critical areas that should remain free of roads to help ensure the long-term survival of apes and their habitats.

**Photo:** Bwindi's global importance was recognized in its designation as a UNESCO World Heritage site, particularly in view of the diversity of its habitats and its exceptional biodiversity. Bwindi hills.  
© Martha M. Robbins/  
MPI-EVAN

## Protected Area Downgrading, Downsizing and Degazettement (PADDD) in Africa

### Documented PADDD Events

As development pressures increase, designated protected areas are sometimes diminished by legal means (Mascia and Pailler, 2011). In Africa, for instance, states have been known to reduce the size, contiguousness and protection status of reserves to allow new roads, mining, energy projects and other activities to expand. At least 23 African protected areas have been downsized or downgraded (Edwards *et al.*, 2014, table 1). Mining occurs more frequently in close proximity to protected areas in Africa than in either Asia or Latin America (Durán, Rauch and Gaston, 2013). Even natural World Heritage Sites, the global pinnacle of conservation, have been subjected to mining or fossil fuel exploration or development, with 30 sites in 18 African countries affected to date (WWF, 2015a). In the Republic of Guinea, for example, the Mount Nimba Biosphere Reserve, a World Heritage site, was downsized by 15.5 km<sup>2</sup> (1,550 ha) to allow for iron ore prospecting. An even greater concern is Zambia, where nearly 650 km<sup>2</sup> (65,000 ha) of land within 19 protected areas has been downgraded to permit mining activities (Edwards *et al.*, 2014).

A number of protected areas with key African ape habitats are under growing development pressures. In Nigeria, for example, a proposed “superhighway” would increase deforestation and other pressures on Cross River National Park, critical habitat for the endemic Cross River gorilla (*Gorilla gorilla diehli*) (see Case Study 5.1). Meanwhile, one of only two surviving populations of mountain gorillas, in Uganda's Bwindi Impenetrable National Park, could also be threatened by a major road-upgrading project inside the park (see Box 4.2).

### BOX 4.2

#### Alternatives to Road Development in an Iconic African Park

Bwindi Impenetrable National Park in the southwest of Uganda supports a highly diverse range of plant and animal species, including the endangered eastern chimpanzee (*Pan troglodytes schweinfurthii*) and one of only two remaining populations of the critically endangered mountain gorilla (*Gorilla beringei beringei*) (Plumptre *et al.*, 2007, 2016a; Plumptre, Robbins and Williamson, 2016c).

Although it is relatively small (321 km<sup>2</sup>/32,100 ha), Bwindi contributes to local and national economies through Uganda's nature-based tourism industry and other ecosystem services the park provides. Its global importance was recognized in its designation as a UNESCO World Heritage site in 1994, particularly in view of the diversity of its habitats and its exceptional biodiversity, including Albertine Rift endemics (UNESCO WHC, n.d.).

In 1995 the aid agency CARE commissioned a study to assess the feasibility of diverting part of the Ikumba–Ruhija road, which cuts through Bwindi for 12.8 km, to land outside the park's boundaries. The study concluded that a road diversion was feasible, identified suitable alternative routes and indicated that a new route would promote long-term protection of the park while boosting economic activity in the area (Gubelman, 1995).

However, in 2012, the Ugandan government advertised a scheme to design and construct 1,900 km of new roads in the country, including an upgrade of the road inside Bwindi, whose clay surface was to be converted to a paved road as part of a much larger road circuit (Kampala, 2012). At the time of writing, an environmental impact assessment to identify the potential effects of the proposed road upgrade on the park's ecology and wildlife had yet to be conducted.<sup>2</sup>

Concerned that the proposed upgrade could harm the park's mountain gorillas and that it might provide few benefits for local villages outside Bwindi, the International Gorilla Conservation Programme





► (IGCP)<sup>3</sup> partnered with the Conservation Strategy Fund and the National Environment Management Authority of Uganda to assess the upgrade scheme and to contrast it with the earlier plan to divert the road outside the park, as part of the Biodiversity Understanding in Landscape Development project, funded by the United States Agency for International Development.

This analysis showed that an alternative route, while costing more initially, would provide greater benefits for twice as many villages and would avoid the negative impacts on the park's gorillas. Furthermore, the study suggested that the government's plan would cost the economy upwards of US\$214 million in tourism revenue losses over the 20-year life cycle of the road investment (Barr *et al.*, 2015). These results were presented to the Uganda National Roads Authority and the Uganda Wildlife Authority.

Based on the results, representatives from the Uganda chapter of the Poverty and Conservation Learning Group conducted consultations with affected communities and prepared a position paper that supported diverting the road around the park (U-PCLG, 2015). During a meeting in March 2015, local stakeholders supported the view that road development around Bwindi is extremely important, and the government was urged to pursue the option of investing in diverting the road outside of Bwindi.

To date, however, the relevant government authorities have not changed their position. Government agencies claim they lack the funds needed to divert the route and compensate local land owners. Local and international stakeholders, including the IGCP, are continuing to urge the government to divert the road outside Bwindi and to take all steps necessary to protect Bwindi Impenetrable National Park and its iconic wildlife.

## Prospects for PADDD

As infrastructure and resource-extraction projects proliferate across Africa, the potential for further PADDD events could increase dramatically. One tool that has considerable utility for monitoring threats to parks is a global database known as the Digital Observatory for Protected Areas (DOPA). DOPA provides a wide range of indicators of park features, habitats, species composition, irreplaceability and threats (see Box 4.3). These metrics could be used to monitor changes over time for a single park and to assess national trends in park protection. Comparisons of environmental threats across parks in different ecoregions or nations need to be conducted carefully because of potential differences in data quality and normalization procedures.

The research conducted for this chapter involved an evaluation of the practical utility of DOPA for assessing threats to parks. To that end, the effects of two factors that could influence the proliferation of roads inside parks were compared: park area and road pressure immediately outside the park. The study hypothesis held that larger parks would have fewer roads than smaller ones,

and that parks with many surrounding roads would also have many internal roads.

For purposes of this research, road pressure inside the park was defined as the total number of kilometers of road length (km) divided by park area (km<sup>2</sup>). To quantify external road pressure, a 30-km buffer zone was defined around each park and an inverse distance–weight function was used to calculate pressure from all roads inside the buffer zone. This approach applies greater weight to roads near a park than to those farther away. In all cases, gROADS was used to generate data on roads (see Box 4.1).

The analysis generated data for 656 protected areas within ten countries in equatorial Africa:

- Cameroon;
- the Central African Republic;
- the DRC;
- Gabon;
- Ghana;
- Ivory Coast;
- Liberia;
- Nigeria;
- the Republic of Congo; and
- Sierra Leone.

Not all protected areas in these nations harbor apes or ape habitats, nor were all protected areas with African ape populations included in the analysis. Via a generalized linear mixed-effects model, “nation” served as a random variable, in order to reduce differences in road-map quality at the national level.<sup>4</sup>

Despite limitations in the available data sets, the results of the analysis appear clear: road pressure inside each park was strongly influenced by its external road pressure, but park size had a weaker and less consistent influence (see Figure 4.5).<sup>5</sup> These findings suggest that as roads proliferate across equatorial

### BOX 4.3

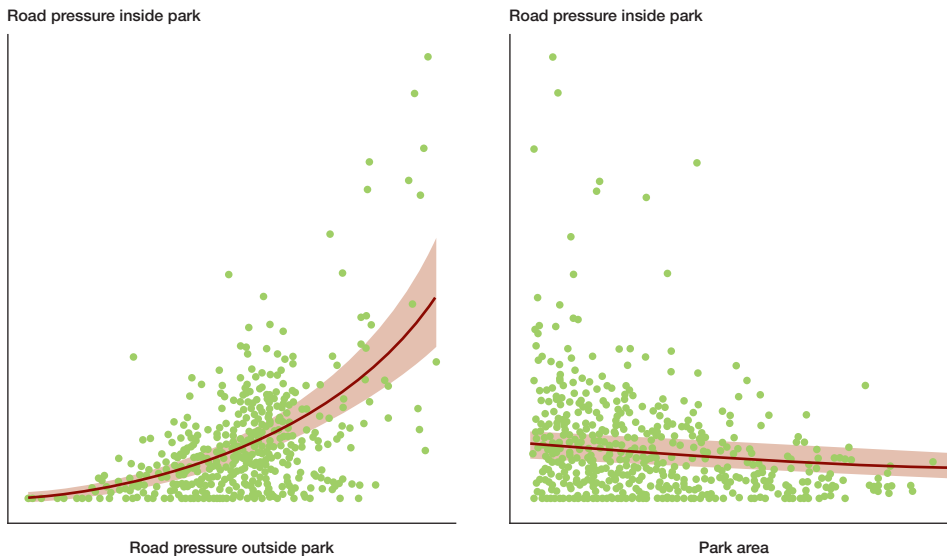
#### Digital Observatory for Protected Areas (DOPA)

DOPA ([dopa.jrc.ec.europa.eu](http://dopa.jrc.ec.europa.eu)) is an online system developed by the European Commission’s Joint Research Centre to provide key indicators of the pressures facing more than 16,000 terrestrial and marine protected areas, each of which exceeds 100 km<sup>2</sup> (10,000 ha) (Dubois *et al.*, 2015). DOPA uses freely available open data for its calculations.

DOPA provides a variety of information, including on the size, location, boundaries and protection status of each park; ecoregions, soils, topography, climatic and land cover data; and the number of threatened species of mammals, birds, amphibians and other selected taxa. It also features indices of species irreplaceability and measures of environmental pressures for five parameters, namely human population density around the park, the annual rate of change in the human population around the park, agriculture surrounding the park, roads inside the park and roads surrounding the park (Dubois *et al.*, 2015).

**FIGURE 4.5**

Effects of External Road Pressure and Park Area on Internal Road Pressure for 656 Protected Areas in Ten Nations in Equatorial Africa



**Notes:** Curves show predicted values; shaded areas are 95% confidence intervals. Each curve shows the effect of the predictor variable on internal road pressure once the effects of the other predictor and cross-national differences were statistically removed.

Africa, protected areas could experience marked increases in internal road pressure. The effects of park size are variable, although the largest parks rarely suffered high internal road pressure.

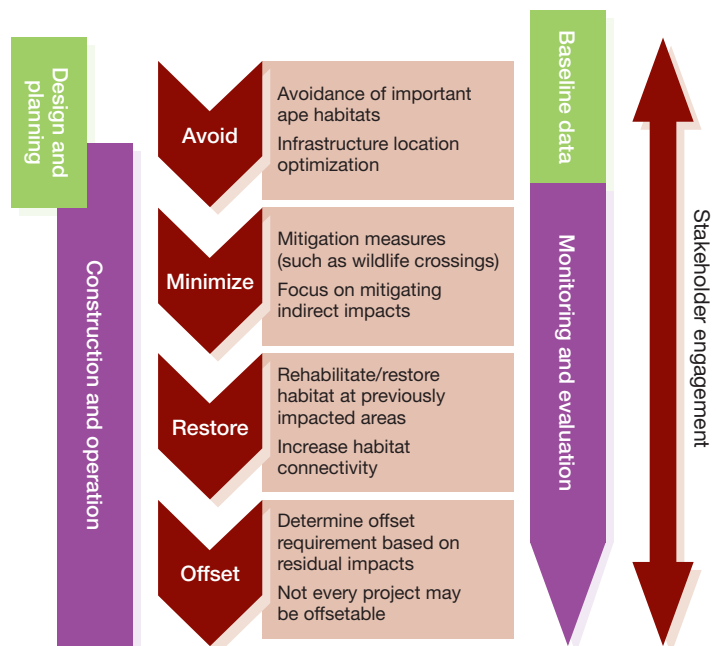
## The Mitigation Hierarchy: Reconciling Infrastructure and Ape Conservation

### The Mitigation Hierarchy

Given the likelihood that many large-scale infrastructure projects will proceed, a major priority is to limit their various direct and indirect environmental impacts. The mitigation hierarchy can be applied throughout the life cycle of a project to aid the process of constructive engagement (see Figure 4.6 and Table 3.3). It aims to minimize negative impacts and to offset any significant impacts that remain (TBC and CSBI, 2015). A new report from Forest Trends identifies that “the

**FIGURE 4.6**

The Mitigation Hierarchy Applied to Infrastructure Projects within Ape Habitats



Source: © TBC, 2017



energy, transportation, and mining/minerals sectors were responsible for more than 97% of offsets and compensation measured by cumulative land area under management” (Bennett, Gallant and ten Kate, 2017, p. 5).

The mitigation hierarchy is increasingly required by project lenders, including the International Finance Corporation and World Bank (IFC, 2012c; World Bank, 2017). It is also becoming integrated into environmental legislation around the world, including in many ape range states (TBC, 2016). The hierarchy follows four sequential steps: avoid, minimize, restore and offset.

### Step 1: Avoid

When operating in ape habitat, the first step, avoidance, is the most crucial and effective. It requires early data gathering and planning, ideally at the start of the design and planning phase (see Figure 4.7).

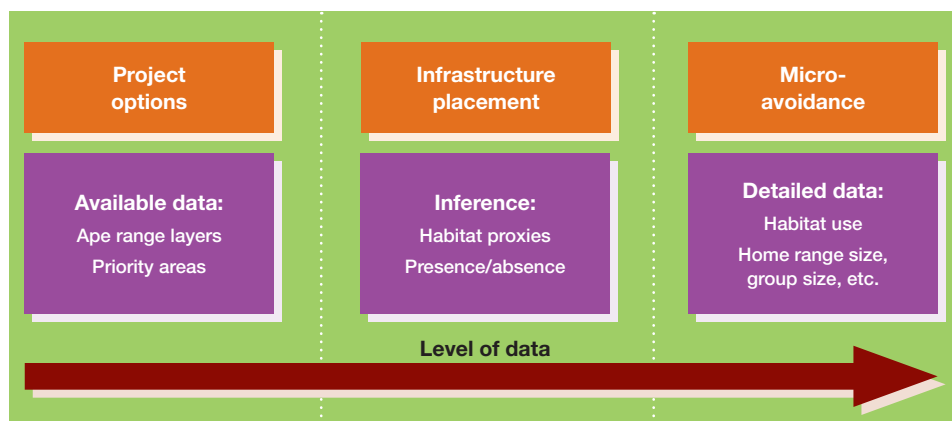
The consideration of alternative routes or project siting is an important early task as it may allow important ape habitat to be avoided. At this stage, projects are rarely able to finance extensive data collection and instead rely on readily available data. Available maps of priority areas for ape con-

servation, such as those produced by regional or national action planning processes, can be extremely useful (Golder Associates, 2015; Rio Tinto Simfer, 2012b). However, companies that design infrastructure projects may not be aware of such data, and therefore ape conservationists may need to take the initiative of sharing data in usable formats and of directing decision-makers to available resources, such as the A.P.E.S. Database (Max Planck Institute, n.d.-b).

Once a broad project option has been adopted, finer-scale optimization of infrastructure placement can further ensure that construction is avoided in sensitive ape habitat. This requires more detailed information on ape distribution and habitat use in relation to proposed infrastructure locations, as can be gathered via surveys conducted as part of environmental and social impact assessments (ESIAs). For example, the ESIA for the Simandou Iron Ore Project in Guinea revealed that chimpanzees principally used the western side of the mining concession. As a result, all mine-associated infrastructure was relocated to an economically suboptimal location in the east of the concession, to avoid important chimpanzee habitat (Rio Tinto Simfer, 2012a).

**FIGURE 4.7**

**Levels of Data Required to Inform Avoidance Measures in the Mitigation Hierarchy**



Source: © TBC, 2017

## Step 2: Minimize

If it is not possible to avoid impacts on apes and their habitat entirely, minimization measures can often reduce the extent and intensity of remaining negative impacts. In addition to being good practice, minimization measures, such as noise and dust reduction and ape-specific measures, may be appropriate. Sufficient ecological data are required to guide informed planning of minimization actions for apes. If there is uncertainty, monitoring and adaptive management may be required.

For apes the indirect impacts of large infrastructure projects, particularly increased poaching and habitat loss due to induced access and in-migration, are usually the most serious (IUCN, 2014b; Vanthomme *et al.*, 2013). These impacts can occur on a large scale and thus effective minimization measures may also need to be implemented at large scales. Such minimization efforts were made in the context of the public–private partnership between the government of Cameroon and the private railway developer CAMRAIL, with the aim of reducing the illegal transport of wild meat, including chimpanzee, that could be facilitated by the railway (Chaléard, Chanson-Jabeur and Béranger, 2006).

Minimization measures can be capital-intensive while also requiring ongoing investment by infrastructure developers. It can therefore be difficult to demonstrate the business case for minimization if data or experience is limited. Such is the challenge regarding wildlife crossings, including artificial canopy bridges. While they have been shown to be effective at maintaining connectivity for the more arboreal gibbons and orangutans, these bridges have never been trialed with African great ape species (Das *et al.*, 2009; see Box 2.2). Hence, their effectiveness at facilitating movements, and their potential for making apes more vulnerable to poaching, are unknown. Other

impacts of infrastructure projects that are poorly understood include tolerable noise levels and the potential barrier to ape dispersal caused by large-scale linear infrastructure projects.

## Step 3: Restore

Complete restoration of ape habitat may not be possible or achievable within a project timeline, and thus it may be more suitable to consider habitat rehabilitation. Examples of rehabilitation measures include planting native tree species, preventing uncontrolled burning and removing damaging species (mainly non-native or invasive species).

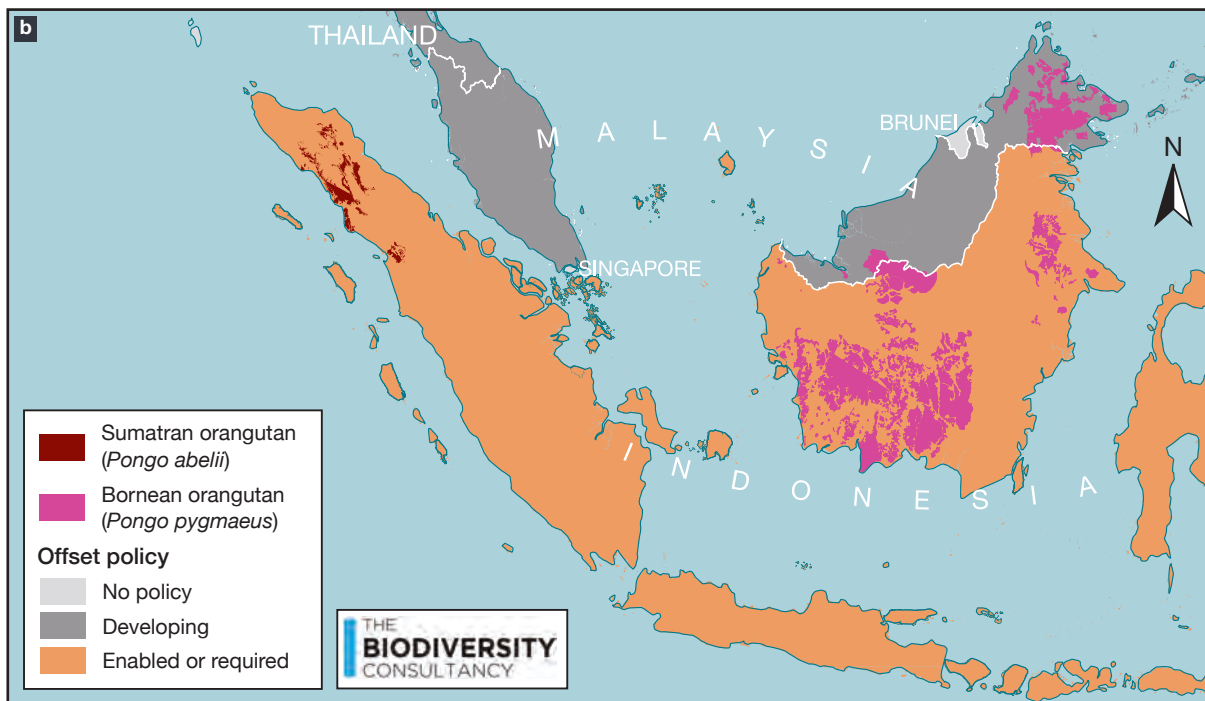
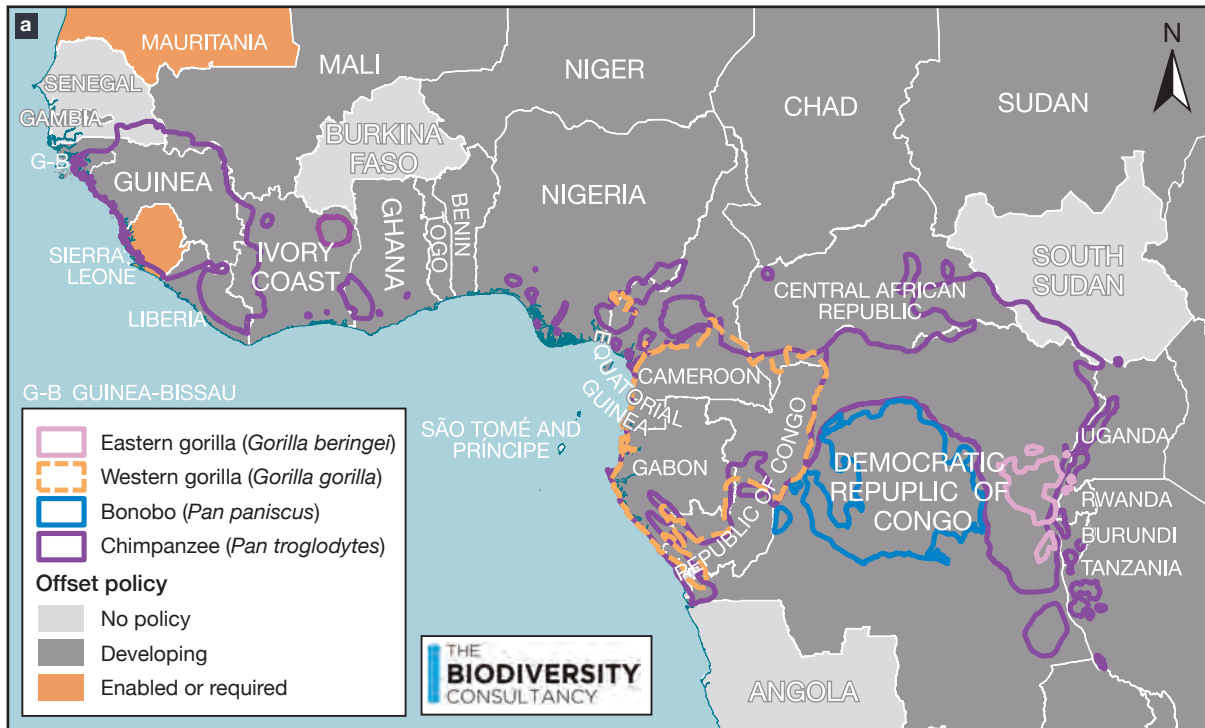
Habitat rehabilitation is a long-term process. Apes use complex habitat and often rely on tree species that take many years to reach maturity. Native tree species used by apes may also require special conditions to grow that are challenging to re-create. It is thus nearly impossible to re-create original habitats and, as a result, it is not possible to rely on restoration actions to make a significant contribution to reducing the magnitude of project impacts on apes (Maron *et al.*, 2012). Nonetheless, targeted habitat rehabilitation can serve as a valuable means of increasing habitat connectivity in fragmented landscapes.

## Step 4: Offset

Any negative impact that remains after the first three steps of the mitigation hierarchy have been applied is termed a “residual impact.” Offsets of such impacts are measures of last resort; their use with respect to threatened and charismatic species such as apes is often seen as controversial (Kormos *et al.*, 2014). If they are poorly planned, large-scale infrastructure projects can have significant indirect impacts that are difficult or impossible to offset. This underscores the need to focus on avoidance and mitigation measures to minimize residual impacts.

**FIGURE 4.8**

Ape Range Countries with an Offset Policy (as of 2016) for (a) Bonobos, Chimpanzees and Gorillas; (b) Orangutans; and (c) Gibbons







Several ape species and subspecies have very restricted geographic ranges (see the Apes Overview). A project that would have a negative impact over a significant extent of a species or subspecies' range would be difficult or impossible to offset, and thus would be unlikely to be supported by conservation stakeholders. Similarly, impacts that compromise the viability of identified regional priority areas for ape conservation may not be considered eligible for offsetting.

For projects associated with less serious residual impacts, the offset requirement is guided by aspects of the biology and behavior of apes, although it is also important to consider uncertainty in estimates of both the scale of impact and the scale of gains at the proposed offset site. Furthermore, the project would need to demonstrate that planned actions have an additional beneficial effect (over and above the status quo) and that they would contribute to an increase in the ape

population in the long term (Kormos *et al.*, 2014). These requirements mean that the loss of even a few individual apes could translate into very significant offset requirements to meet “no net loss” definitions (IUCN, 2014a).

Offset requirements to compensate for impacts of development projects are increasingly becoming integrated in national legislation (ten Kate and Crowe, 2014). In Asia, most orangutan and gibbon range states have legislation either requiring or enabling biodiversity offsets, while many African ape range states are developing such national policies (TBC, 2016; see Figure 4.8). There is thus an opportunity for governments and ape conservationists to work together to ensure such policies provide appropriate protection for apes and their habitat.

## The Importance of Stakeholder Engagement

Apes are iconic animals and any negative impacts on them or their habitats attract high interest and scrutiny from the general public, stakeholders and lenders. Therefore, infrastructure developers face potentially serious reputational risks when operating within ape habitat, which makes consultations with stakeholders and ape experts at an early stage advisable. Stakeholders such as universities and conservation groups can provide specialized knowledge that can be input into the project design and add credibility to a project, while reducing impacts on apes. Engagement with stakeholders is most effective when it begins in the early stages of a project and continues throughout its life span, through every step of the mitigation hierarchy.

## Cumulative Impacts and the Mitigation Hierarchy

Cumulative impacts are defined as the incremental impacts of one project, combined with the past, present and foreseeable impacts

arising from other developments (such as infrastructure, extractive or agricultural activities) within the same geographic and connected areas (IFC, 2012b). Cumulative impacts often arise when a country is undergoing rapid development, for example when multiple dams are planned for construction on the same river (Winemiller *et al.*, 2016). Environmental impact assessments for any single project often fail to adequately consider the wider or additive effects of other projects in the same vicinity (Laurance *et al.*, 2015a; see Chapter 1, p. 32). This can be severely detrimental to species such as apes, as numerous projects have large impacts across populations and reduce population connectivity.

There has been increasing pressure from stakeholders for individual projects to take cumulative impacts into consideration. Best-practice guidelines require cumulative impact assessments (CIAs); in practice, this step often receives insufficient attention or is omitted completely. A major barrier is the lack of clarity about whose responsibility it is to organize and pay for a CIA, particularly in a landscape that comprises multiple development projects with different timelines. However, if conducted rigorously and systematically, CIAs could greatly strengthen regional and national planning processes (IFC, 2013).

When adhering to the mitigation hierarchy, projects should take cumulative impacts into account (see Case Study 4.1). Ideally, neighboring projects would adopt coordinated mitigation measures and would be designed to share common infrastructure (such as railways and access roads) to reduce their footprint area. Governments can facilitate the management of cumulative impacts by carrying out strategic land use planning at the national or landscape scale, thereby preventing projects with competing interests (such as ape conservation and industrial development) from operating in the same area. Additional case studies

### CASE STUDY 4.1

#### The Mitigation Hierarchy and Cumulative Impacts: A Case Study from Guinea

The Republic of Guinea in West Africa has large mineral deposits such as bauxite, gold and iron and its mining sector is undergoing rapid development. Major deposits can be found in different parts of the country, often inland, far from the coastline. Large infrastructure projects, such as railways and roads, are being planned to transport ore from mine sites to seaports for export to international markets (Republic of Guinea, n.d.).

Bauxite reserves in Guinea are concentrated in the north-west of the country, where they overlap with the range of the critically endangered western chimpanzee (*Pan troglodytes verus*) (Humble *et al.*, 2016a). Several mining companies are active in this region and hold adjacent concessions. Most projects are operating independently and have not yet effectively tackled the issues related to cumulative impacts. Two neighboring companies, however, are working towards implementing international best-practice standards and addressing cumulative impacts. These companies—the Compagnie des Bauxites de Guinée (CBG) and Guinea Alumina Corporation (GAC)—need to develop or upgrade roads to transport their bauxite ore to a port site located about 140 km away.

They will share an existing railway so that they may reduce their cumulative impact (see Figure 4.9).

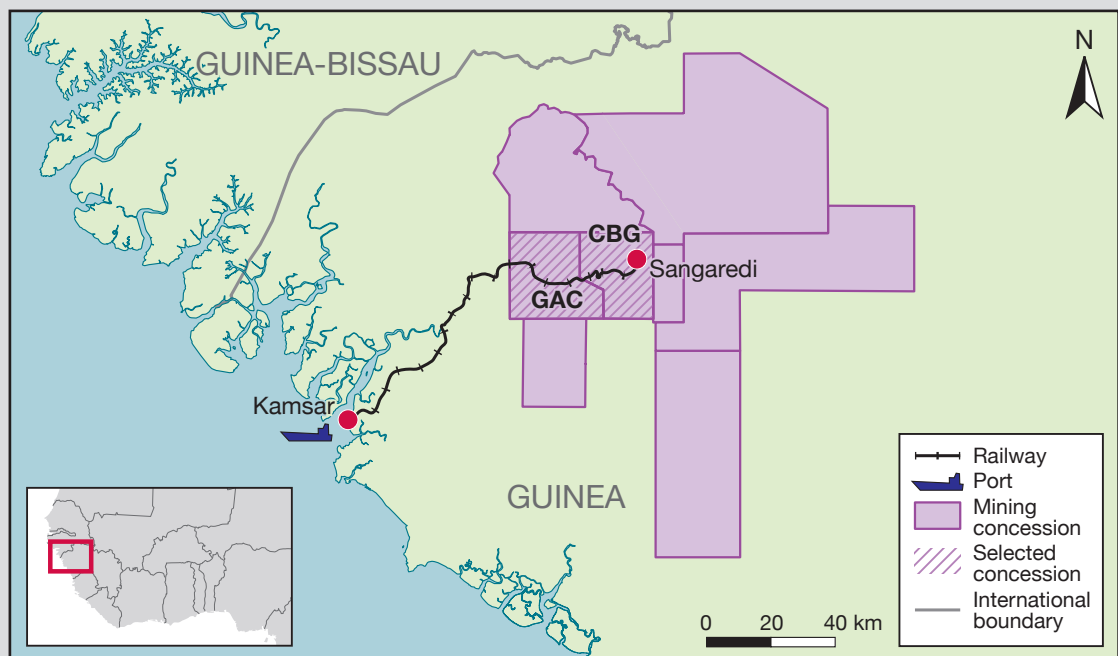
Following the mitigation hierarchy, both companies are considering the option of setting aside a portion of their concessions to avoid sensitive chimpanzee habitat. Extensive surveys for chimpanzees have been conducted to help inform mitigation planning. Mitigation measures, which were developed to minimize both direct and indirect impacts, are outlined in each company's biodiversity action plan.

GAC has also established a nursery with native tree species that are known to be used by chimpanzees for feeding and nesting. These species will be used to rehabilitate areas previously impacted by the project as well as other degraded areas that were cleared by the local population using slash-and-burn cultivation.

Despite the various measures, preliminary assessments show that both companies will have residual impacts on chimpanzees; offset requirements were thus estimated separately for each company. As Guinea lacks national offset planning and updated maps of priority areas for chimpanzees, GAC has supported a nationwide chimpanzee survey to find the most appropriate offset site. This site may be large enough to provide an aggregated offset, where other companies could also contribute towards protecting a large population of the western chimpanzee.

**FIGURE 4.9**

Locations of the CBG and GAC Mining Projects and the Railway to Be Shared, Guinea



Sources: © TBC, 2017

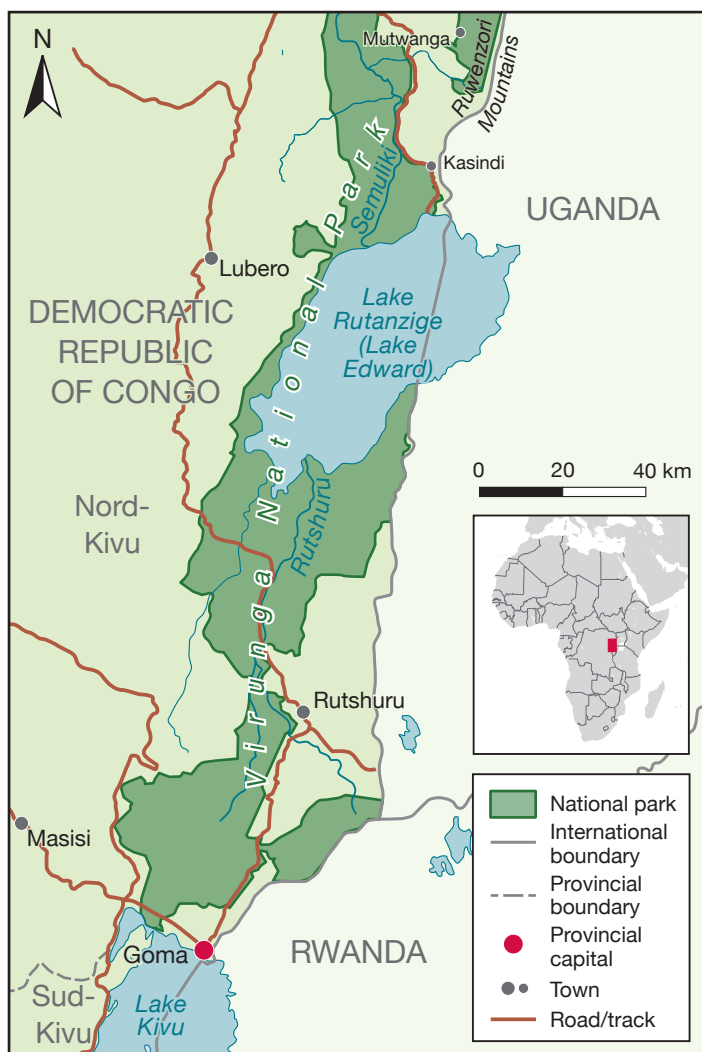


and information on the mitigation hierarchy are available on the website of the Business and Biodiversity Offsets Programme (<http://bbop.forest-trends.org/>).

With its rapidly growing populations, a dire need for economic and social development, and exceptional natural riches, Africa represents serious challenges for environmental planners and managers. Unless these challenges can be addressed meaningfully, social instability and serious environmental damage will be unavoidable. The worst-case

**FIGURE 4.10**

**Virunga National Park**



**BOX 4.4**

**Virunga National Park:  
Promoting Socioeconomic  
Development alongside  
Conservation**

The history of the Democratic Republic of Congo (DRC) is characterized by the exploitation of its vast natural resources. Yet despite the abundance of this natural wealth, extreme poverty has spread throughout the country. This paradox is exemplified by the DRC's water crisis: notwithstanding its immense freshwater resources, only 25% of the population has access to safe drinking water (and only 17% in rural areas), one of the lowest rates in sub-Saharan Africa (WSP, 2011). The legacy of colonialism, state collapse during the Mobutu years and recurring armed conflicts—of which the most significant followed the Rwandan genocide—have left the DRC with weak institutions and a chronically defective public infrastructure, particularly in the eastern provinces.

The catastrophic loss of life among civilians during the conflict years was principally attributable to indirect public-health effects, such as the dysfunction of water and sanitation infrastructure. Despite the international community's investments in peacekeeping, development aid and humanitarian relief (at an annual cost of up to US\$15 billion), little has been achieved to prevent a resurgence of armed conflict.

In the face of overwhelming challenges, a community of institutions—the Institut Congolais pour la Conservation de la Nature (ICCN)—is working in partnership with the Congolese authority for conservation in Virunga National Park, in the eastern DRC (Figure 4.10). ICCN has invested more than US\$60 million<sup>6</sup> to develop a holistic approach to social justice and conservation in this conflict-ridden region.

Virunga is Africa's oldest national park and a UN World Heritage Site, home to mountain gorillas and chimpanzees, as well as other endangered and endemic wildlife. It is plagued by ungoverned resource extraction as members of local communities hunt for food, clear forest for agriculture and gather fuelwood and charcoal for energy, lighting and heating.

**TABLE 4.1****The Virunga Alliance's Hydropower Plan**

	River/population center	Power	Users
Phase I	Butahu/Mutwanga	0.4 MW	1,200
Phase II	Volcano/Lubero	15.0 MW	160,000
	Rutshuru I/Rutshuru II	12.6 MW	140,000
Phase III	Various sites	80.0 MW	840,000

Source: Virunga National Park (n.d.).<sup>7</sup>

Along with the ICCN, a wider investment program known as the Virunga Alliance draws on the resources of the park to deliver broad-based services to the community in a way that is sensitive to the environment, focused on the needs of the poorest and most vulnerable, and supportive of stability in the region. Established in 2009, the Virunga Alliance was developed as three programs that may be visualized as concentric circles. The innermost circle is focused on conservation and protection of the park, as well as tourism. The second relates to socioeconomic development through the four main sectors of development: sustainable energy, tourism, agro-industry, sustainable fisheries, as well as measurable improvements in local infrastructure. These programs target the local population—principally the six million people in North Kivu (MONUSCO, 2015). The third circle targets private-sector investment to stimulate the local economy and to help bring people out of the cycle of poverty. Using a business approach to service delivery, the Alliance generates dividends from tourism and energy provision to industry, and reinvests these funds into the conservation and social infrastructure of the park.

Virunga's program of socioeconomic development—the second circle—focuses on renewable energy, sustainable fisheries, agro-industry and tourism. The region has vast natural wealth, including fertile soil, regular rainfall and abundant hydrological resources. The park's rivers feed Lake Edward, which flows into the Semliki River to form the source of the Nile. Millions of people depend on the park's healthy rivers and lake. There is very little infrastructure, however, to provide the local people with adequate water and energy supplies. The Virunga Alliance is working to supply hydroelectric power to nine towns in North Kivu on a build–operate–transfer basis. Eight hydropower plants, with the effective capacity of 108 megawatts (MW), and two interconnected networks will be built over 9 years, with the first completed in 2012 (see Figure 4.10 and Table 4.1). Two plants are already operational. Access to electricity is expected to provide a boost to local agriculture, thus helping to create 80,000 to 100,000 new jobs.

The hydropower feeds a grid, connecting consumers via a prepaid, smart metering system. Each megawatt of electricity is expected to produce as many as 1,000 jobs, based on the results of the Mutwanga hydroelectric pilot project in the north of the park, which was completed in 2013. The Matebe plant and Rutshuru grid are expected to create 13,000 permanent jobs, mostly in the small business sector.

There is a sizeable waiting list of consumers and small businesses that want to be connected to the grid, as grid electricity is substantially cheaper than the current power source—diesel generators. Indeed, a typical small business would save US\$17 per month on power costs by connecting to the grid. This is a saving of US\$204, which is more than half the average annual income (\$394.25; Tasch, 2015). At present, the Mutwanga hydroelectric facility, managed by the park authority, provides electricity free of charge to schools and hospitals in the region.

The Virunga program assumes that increasing private-sector investment will accelerate economic development catalyzed by the hydroelectric program. Until now, Virunga has lacked a practical strategy to provide funding to small local businesses. Identifying a viable instrument for financing small Congolese-owned businesses is vital. The program is developing a Smart-Grid Small Business Loan Fund, capitalized with equity funding (grants or unsecured loans); the fund will approve, disburse, monitor and collect repayments on loans to small businesses that are also clients of the Virunga power grid.

The overall goal of the Virunga Alliance is to contribute to peace and prosperity via responsible economic development of natural resources for four million people who live within a day's walk of Virunga Park's borders. Economic opportunities and access to social services are an important factor in maintaining a long-term solution to violence. For the Virunga Alliance, a minimum of 30% of the park's revenues are invested in community development projects, which have been identified and defined by the local communities on the principle of free, prior and informed consent.

scenarios of natural-resource exploitation in Africa—driven by foreign capital, distorted by endemic corruption and resembling “feeding frenzies” of predatory behavior (Edwards *et al.*, 2014)—are far too common. At the same time, innovative initiatives that are well planned and executed, attuned to social needs and sustainability outcomes, and long-term in nature are rare.

Africa does have a few examples of enlightened infrastructure projects—ones driven by visions of social and environmental betterment (see Box 4.4). Such endeavors, woven integrally into the surrounding cultural fabric, might be better described as “initiatives” rather than projects, in that their goals are less about generating profits than yielding broad-based social betterment and environmental sustainability.

## Future Threats and Prospects

### Narrow Window of Opportunity

The focus of this chapter is the potential effects of large-scale infrastructure expansion on ape habitats in equatorial Africa. The conclusions, by any measure, are alarming. Without determined efforts to modify, reconsider and mitigate the impact of current development schemes, apes and their biologically rich environments in Africa are likely to suffer irreparable harm.

The threats to African apes and their habitats are imminent, in the sense that many crucial changes will play out over the next 1–3 decades. However, the recent decline in global commodity prices, particularly for minerals and fossil fuels, provides a potential window of opportunity of a few years to employ direly needed land use planning and infrastructure-prioritization schemes (Hobbs and Kumah, 2015).

Two broad developments are critical to the promotion of strategic planning. The first is an expansion of the application of the mitigation hierarchy. The second is the implementation of viable financial strategies designed to help developing nations meet pressing economic and food-production needs while limiting the environmental impacts of rapid infrastructure development. For these nations, payments for ecosystem services, ecotourism and sustainable harvesting of native production forests, as well as strategic investments in natural capital could potentially help to balance economic and environmental priorities (Laurance and Edwards, 2014; see Box 4.5).

At a fundamental level, the challenges affecting Africa arise from its escalating population growth and serious needs for economic and human development, especially increased food security (AgDevCo, n.d.; Laurance *et al.*, 2014b). As noted above, Africa’s current population could almost quadruple this century, although such projections are not carved in stone (UN Population Division, 2017). Importantly, they can be altered by concerted efforts to promote family planning and, particularly, the education of young women. In demographic terms, educating young women has vital benefits, including delaying the age of first reproduction, which reduces average family sizes while increasing the mean generation time, thereby slowing the overall rate of population growth. Educated women with smaller families also enjoy greater marital stability, higher living standards and improved educational and employment opportunities for their children (Ehrlich, Ehrlich and Daily, 1997). Advocating for more sustainable infrastructure while ignoring rampant population growth in Africa is akin to plugging holes in a leaking dam while failing to notice rising floodwaters that threaten to spill over its top.<sup>8</sup>



## BOX 4.5

### Using Natural Capital to Promote Sustainable Infrastructure

#### The Idea

Healthy, intact ecosystems are essential for apes, gibbons and other wildlife. People also rely on these ecosystems for myriad benefits, including:

- medicinal plants;
- water supplies;
- areas of cultural and spiritual importance;
- carbon storage and sequestration; and
- pollination of crops (MEA, 2005).

Reflecting human dependence on nature, natural resources are increasingly viewed as “natural capital” that supplies “ecosystem services” (Kumar, 2011). These economic metaphors emphasize the importance of maintaining our stock of assets over time to ensure a long-term supply of benefits. The concepts can resonate with groups that have previously had limited interest in conservation, including ministries of finance and planning, private investors and business leaders (Guerry *et al.*, 2015; Natural Capital Coalition, n.d.; NCSA, n.d.; Ruckelshaus *et al.*, 2015).

#### The Challenge

It has been estimated that achieving the United Nations Sustainable Development Goals and realizing the climate commitments made in the Paris climate accord of 2016 will require approximately US\$90 trillion in infrastructure investments, particularly in urban development, transportation and clean energy (Global Commission on the Economy and Climate, 2016). A majority of these investments will be in the developing world, including ape and gibbon range states.

This new infrastructure is essential for economic development, poverty reduction and human well-being. If the infrastructure is poorly planned, however, it not only imperils apes and gibbons, but also the benefits that are provided by nature to humans, undermining the very human development that the infrastructure was intended to support (Mandle *et al.*, 2016a).

Environmental issues are typically considered late in the development planning process, and often when only marginal changes to project design can realistically be considered (Laurance *et al.*, 2015a; see Box 1.6). Even though such gaps can be addressed through strategic environmental assessments, impacts on ecosystem services continue to be considered late or not at all, even when an infrastructure project's success depends directly on ecosystems, for example to reduce the risks of flooding or erosion (Alshuwaikhat, 2005; Mandle *et al.*, 2016a). The transformation of this deeply flawed model of infrastructure planning and investment is a matter of critical urgency.

#### The Opportunity

Impacts on natural capital and those who depend on it can best be mitigated if they are centrally integrated into infrastructure planning, assessment and development processes from the outset. This early incorporation can build a pipeline of projects that genuinely take into account interlinked environmental, social and economic considerations. There is considerable demand for such projects: “patient” financial capital is invested to produce high-yielding, stable, long-term, income-oriented returns (Roberts, Patel and Minella, 2015).

Around the world, people are now developing, accessing and sharing information about natural capital to inform development planning (Brown *et al.*, 2016; Guerry *et al.*, 2015). These approaches identify the manifold benefits that nature currently provides and attempt to anticipate what might happen to those benefits in response to global climate change, and as resource management and human interactions with nature change (Ruckelshaus *et al.*, 2015). Tools are being devised to help incorporate environmental priorities into real-world decision-making.<sup>9</sup> Governments and businesses can use this type of information to identify areas that are important sources of natural capital and that should be avoided or protected to minimize the negative impacts of built infrastructure (Laurance *et al.*, 2015b). Such knowledge can also be used to identify positive impacts of ecological restoration—for example, investing in reforestation around rivers to enhance fisheries.

There is also demand from businesses and investors for help in determining the best locations for new infrastructure (Laurance *et al.*, 2015a; Natural Capital Coalition, 2016). Environmental and social impact and risk assessments have often ignored companies' dependence on ecosystem services such as clean air, fertile soil and reliable water supplies. This puts companies at risk—for example, from flooding, drought and shortages that could affect their supply chains. To lessen these risks, companies can incorporate natural capital information in decision-making. The Natural Capital Protocol is a decision-making framework that provides guidance for businesses looking to manage risks and seize opportunities by integrating the value of nature into their internal decision-making (Natural Capital Coalition, 2016).

#### Some Examples

China provides an impressive example of strategic environmental planning at the national scale, one from which lessons can be drawn for ape conservation. In 1998, after decades of deforestation and overgrazing, China instituted major reforms in response to devastating floods that left more than 4,000 people dead and 13 million homeless in the Yangtze River Basin (Spignesi, 2004). Information on how nature benefits people is being used to design restoration and protection measures for ecosystems across almost half of the country. To date, about US\$100 billion has been invested in ecosystems and to compensate 120 million people, with many millions of trees planted (Daily *et al.*, 2013). China's first

**Photo:** Commitments made in the Paris climate accord of 2016 will require approximately US\$90 trillion in infrastructure investments, particularly in urban development, transportation and clean energy, such as hydropower projects.

© Melanie Stetson Freeman/The Christian Science Monitor via Getty Images

national ecosystem assessment—carried out from 2000 to 2010—quantified and mapped changes in food production, carbon sequestration, soil retention, sand-storm prevention, water retention, flood mitigation and the provision of habitat for biodiversity. It showed significant improvements in most services, with the worrying exception of habitat for biodiversity conservation (Ouyang *et al.*, 2016).

Incorporating natural values into project planning also has much potential to contribute to conservation in the ape range states of Africa and Asia, even where data and capacity are limited (Bhagabati *et al.*, 2014; Mandle *et al.*, 2016b; University of Cambridge, 2012; Watkins *et al.*, 2016). In the Greater Virungas landscape, a key region for the conservation of gorillas and chimpanzees in Africa's Albertine Rift, a natural-capital assessment helped decision-makers in Rwanda and the DRC to identify the location and importance of areas for water yield, sediment retention, carbon storage and non-timber forest products (University of Cambridge, 2012). In Myanmar, a national assessment showed where and how natural capital contributes to clean and reliable drinking water, reduces risks from inland flooding and coastal storms, and maintains reservoir and dam functioning by greatly reducing erosion (Mandle *et al.*, 2016b). In Indonesia, natural-capital tools were used to inform spatial planning in Sumatra and Borneo, and at the national level. The informed land use planning will be incorporated into efforts to build governance and financing that improve outcomes for people and biodiversity (Bhagabati *et al.*, 2014; GEF, 2013; Sulistyawan *et al.*, 2017).







### BOX 4.6

#### The Bukavu–Kisangani Highway: A Threat to the Critically Endangered Grauer's Gorilla?

Extending over 6,000 km<sup>2</sup> (600,000 ha), the Kahuzi-Biega National Park (KBNP) in the eastern part of the Democratic Republic of Congo (DRC) comprises dense lowland as well as Afromontane rainforests. The protected area was originally created as a wildlife sanctuary to protect the small population of Grauer's gorilla (*Gorilla beringei graueri*) living in the mountain and bamboo forests between Mounts Kahuzi (3,308 m) and Biega (2,790 m). Having been upgraded to a national park in 1970, KBNP was extended in 1975 to comprise vast

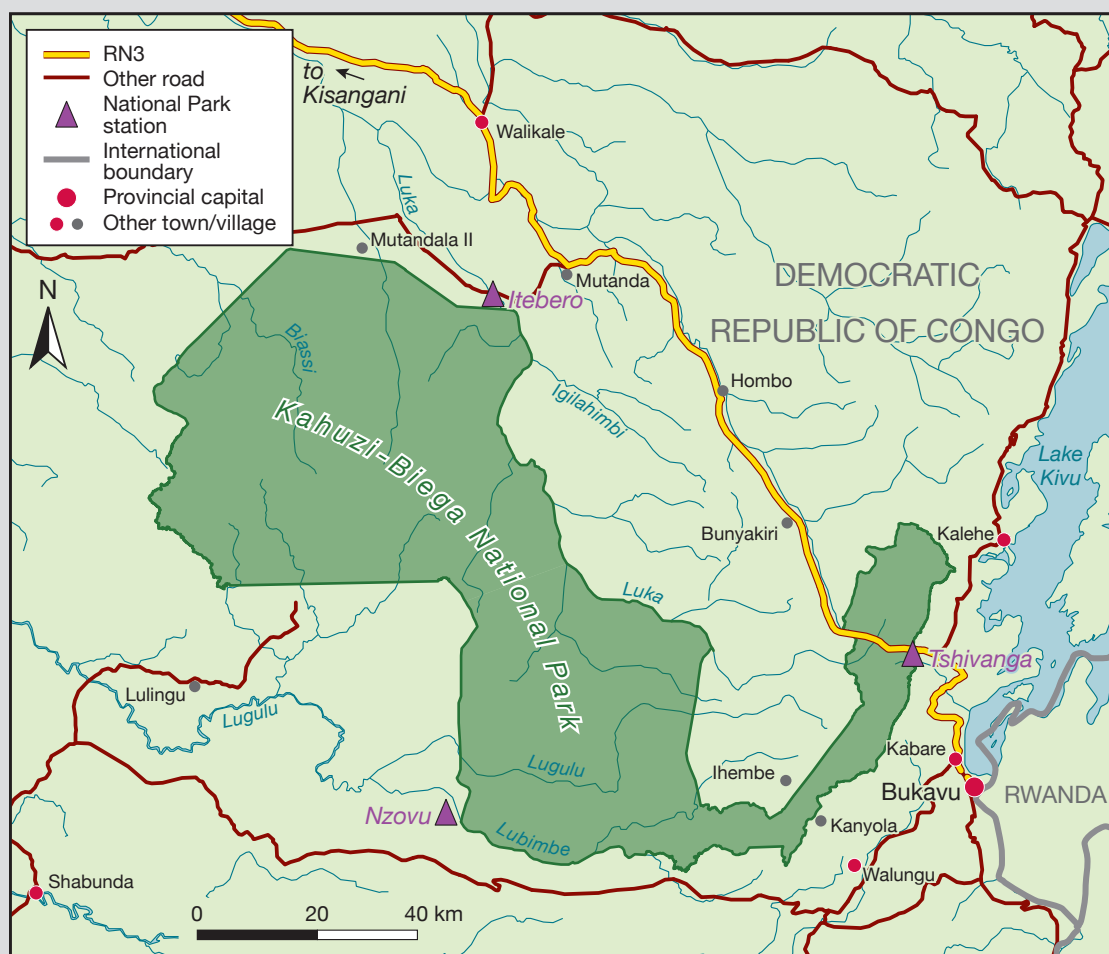
tracts of lowland forests, which make up more than 90% of its surface today (ICCN, 2009).

The park is one of the most important sites for biodiversity in the Albertine Rift and harbors 136 species of mammals, including 14 species of primate, 2 of which are great apes: the eastern chimpanzee (*Pan troglodytes schweinfurthii*) and Grauer's gorilla (ICCN, 2009). In view of this exceptional biodiversity, the park was designated a UNESCO World Heritage Site in 1980. KBNP suffered major impacts during the wars and civil conflicts in the DRC and has thus been on the list of World Heritage in Danger since 1997 (Debonnet and Vié, 2010).

KBNP harbors the largest surviving population of Grauer's gorilla that is endemic to the DRC. However, these apes are

**FIGURE 4.11**

The Bukavu–Kisangani Highway (RN3) and the Kahuzi-Biega National Park



Sources: René Beyers; vector data from CARPE (n.d.); digital elevation model from USGS (n.d.)



increasingly threatened as a result of poaching for wild meat, an illegal activity that is linked to unlawful artisanal mining and the civil conflict. The population has declined by more than 77% since 1994 and is now critically endangered (Plumptre *et al.*, 2016c).

Even before the outbreak of the civil conflict, the upgrade of the RN3, a major road connecting the cities of Bukavu and Kisangani, had raised concerns about possible adverse impacts on the park. The road bisects the highland sector of the park for 18.3 km, cutting through the habitat of several gorilla families (Bynens *et al.*, 2007). After leaving the park, the road veers away from its boundaries before approaching it again in the vicinity of the village of Itebero, in the lowland sector (see Figure 4.11).

The road predates the creation of the national park. Traffic densities remained low until it fell into complete disrepair in the 1990s, when it became virtually impassable. Today, traffic is mostly local, transporting goods and people between Bukavu and the villages to the west of the highland sector. The road's poor condition beyond the village of Hombo has rendered through traffic to Kisangani virtually impossible since the early 1990s. To further mitigate the impacts, the protected area authority—the Institut Congolais pour la Conservation de la Nature (ICCN)—has erected checkpoints at the entry and exit of the park, where vehicles are registered and can be searched. The road is closed to all traffic between 6 pm and 6 am. Nevertheless, vehicles frequently stay in the park at night as a result of mechanical breakdowns or because they get stuck due to poor road conditions.

In spite of the inferior quality of the road, traffic on the stretch through the park has continued to increase. Data collected by the park show an upsurge from 1,485 motorized vehicles in 1999 to 47,489 vehicles in 2014—a 30-fold increase (Bynens *et al.*, 2007; ICCN, 2015). Vehicle numbers vary widely between years, reflecting prevailing security conditions, but the past few years show a clear upward trend, paralleling gradual security improvements (ICCN, 2016). An upgrade of the road would allow vehicles to pass to Kisangani once again and would invite non-local traffic, which could result in a steep increase in traffic through the park.

The impacts of the road on the gorillas in the highland sector are not well understood. The road cuts through the territory of several gorilla families, which cross the road regularly, several times a week. The number of families living around the road and therefore needing to cross it has more than doubled over the years—from three in 2007 to eight in 2015 (ICCN, 2016). This increase may be partly linked to greater insecurity and human activities in the northern and southern parts of the highland sector, where illegal artisanal mining and farming are known to occur; these developments have led to a concentration of gorillas in the central region of the highland sector, which is safer.

Systematic follow-up of gorilla crossings in the early 1990s, when traffic flows were low, suggested that the number of crossings remained stable over time. However, the authors' field observations clearly indicate that road crossings are

highly stressful for the animals. Ranger staff have documented that gorillas sometimes hide close to the roadside for long periods of time, waiting for humans to disappear before starting to cross. During the crossing, the silverback typically takes up a position in the middle of the road and waits for the family to cross safely<sup>10</sup>. It is therefore highly likely that a significant increase in traffic on the road would affect the current crossing patterns (Bynens *et al.*, 2007).

The rehabilitation of the RN3 has been planned for a long time. At the end of the 1980s, rehabilitation started from Kisangani, with funding from the government of Germany. Following concerns raised by environmental experts and by the UNESCO World Heritage Committee, IUCN prepared an environmental impact assessment, which advised against rehabilitating the stretch through the park and recommended that it be rerouted around the northern boundary of the park (Doumenge and Heymer, 1992). Based on the results of the study, the German government informed UNESCO that it would not support the construction of the stretch through the park. As a result of the freezing of German aid to the DRC in 1990, the road was not built beyond the village of Walikale and thus never reached the village of Itebero (Bynens *et al.*, 2007).

In 2007, the European Union undertook a new feasibility study for the rehabilitation of the road. Once again, the UNESCO World Heritage Committee expressed concerns that the measures proposed to lessen the adverse effects of the road in the park were insufficient and requested that the final report include clear proposals for mitigation measures to reduce the direct and indirect impacts (UNESCO, n.d.-a). The final study concluded that while the road would bring important socio-economic benefits to the local communities, the likely steep increase in traffic on the stretch through the park could have adverse impacts on the resident gorilla populations and the integrity of the World Heritage site. It thus recommended that the road be rehabilitated for through traffic to Kisangani only if the stretch through the highland sector of the park could be rerouted to avoid the park (Bynens *et al.*, 2007). Kinshasa accepted this recommendation at the time.

To date, the RN3 remains impassable and no traffic is possible beyond the village of Hombo. A reopening of the road would bring important economic benefits to communities, which have lived in total isolation since the start of the civil conflict, at the mercy of the different armed groups and bandits who control the region. With the gradual return of peace and stability, the discussion regarding the road's rehabilitation will certainly be revived. A rehabilitated road would undoubtedly attract new threats to the lowland sector of KBNP, and it might increase illegal logging and stimulate the wild meat trade. At the same time, it would reintegrate this region into the modern world, allowing park authorities to exert better control over illegal activities. It would also persuade people who had settled inside the park after fleeing the violence to leave the park and resettle in the villages along the road; in this way, a revitalized road could garner conservation benefits. However, the rerouting of the stretch crossing the highland sector of the park remains an important condition that needs to be guaranteed before any rehabilitation is envisaged.



## Priorities for Infrastructure and Protected Areas

Near-term priorities for limiting the environmental impacts of infrastructure expansion on African ape habitats and, more generally, vital protected areas include:

- Carefully scrutinizing plans for expanding “development corridors” in Africa in terms of their environmental costs and economic and social benefits (see Chapter 1). Taking this approach calls for the substantial modification or total abandonment of corridors that are likely to produce marginal benefits relative to their heavy costs, regardless of whether they are being planned or already being upgraded (Laurance *et al.*, 2015a; Sloan *et al.*, 2016).
- Limiting roads in and near protected areas. While protected areas need some road access for ecotourism, roads should avoid the core areas of parks whenever possible so as to limit human impacts. A variety of sensitive wildlife species shun areas with even modest levels of human activity (Blake *et al.*, 2007; Griffiths and Van Shaik, 1993; Ngoprasert, Lynam and Gale, 2017; Reed and Merenlender, 2008; Rogala *et al.*, 2011).
- Stemming the loss of buffering habitats and limiting infrastructure expansion in the habitats immediately surrounding protected areas. Unless they are curbed, these processes (1) reduce the ecological and demographic connectivity of reserves to nearby habitats, and (2) often “leak” into the interiors of protected areas themselves (see Figure 4.5). Both types of

changes can have serious impacts on biodiversity (Laurance *et al.*, 2012).

- Favoring large protected areas, which are superior to smaller protected areas because they typically (1) are less susceptible to human encroachment and external land use disturbances (Maiorano, Falcucci and Boitani, 2008; see Figure 4.5), (2) support larger wildlife populations that are less vulnerable to local extinction, and (3) provide a wider range of habitats, elevational and topographic diversity, as well as climatic regimes that can help buffer species against heat waves, droughts and other severe climatic events (Laurance, 2016b).
- Defending protected areas for African apes and designating new reserves in critical habitats. Two immediate priorities are Cross River National Park in Nigeria (see Case Study 5.1) and Kahuzi-Biega National Park (see Box 4.6) and its nearby critical habitats in the eastern DRC (Plumptre *et al.*, 2015). Both parks harbor critically endangered subspecies of gorillas.

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**Mitigation Hierarchy and Case Study 4.1:**  
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**Boxes 4.1 and 4.3:** Stephen Peedell

**Box 4.2:** Anna Behm Masozera and Stephen Asuma

**Box 4.4:** Ephrem Balole and Emmanuel de Merode

**Box 4.5:** Emily McKenzie and Neil David Burgess

**Box 4.6:** Guy Debonnet and Sivha Mbake

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**Photo:** KBNP harbors the largest surviving population of Grauer's gorilla. The population has declined by more than 77% since 1994 and is now critically endangered. © Jabruson 2018 ([www.jabruson.photoshelter.com](http://www.jabruson.photoshelter.com))

## Endnotes

- 1 Two additional proposed corridors came to light during the study, making the total 35.
- 2 Author correspondence with Tom Okurut, executive director of the National Environment Management Authority, Uganda, 2016.
- 3 IGCP is a coalition program of Fauna and Flora International and the World Wide Fund for Nature, alongside the protected area authorities in the DRC, Rwanda and Uganda and local partners. <http://igcp.org/>
- 4 All variables were  $\log_{10}$  transformed and then standardized prior to analysis.
- 5 Significance testing was carried out for external road pressure ( $t=13.72$ ,  $df=651$ ,  $P<0.000001$ ) and park size ( $t=-2.65$ ,  $df=651$ ,  $P=0.008$ ).
- 6 Internal calculation based on confidential ICCN documents reviewed by the author.
- 7 Some figures have been adjusted based on internal ICCN project update and assessment documents reviewed by the author.
- 8 The average woman in Africa had 4.72 children in 2010–15, exceeding the global fertility rate of 2.52 by about 87% (UN Population Division, n.d.).
- 9 See the Natural Capital Protocol Toolkit for information on a variety of available tools (WBCSD, n.d.).
- 10 In 1997, a soldier killed one of the park's most famous silverbacks, named Nindja, while he was standing in the middle of the road waiting for his family to cross.
- 11 James Cook University ([www.jcu.edu.au](http://www.jcu.edu.au))