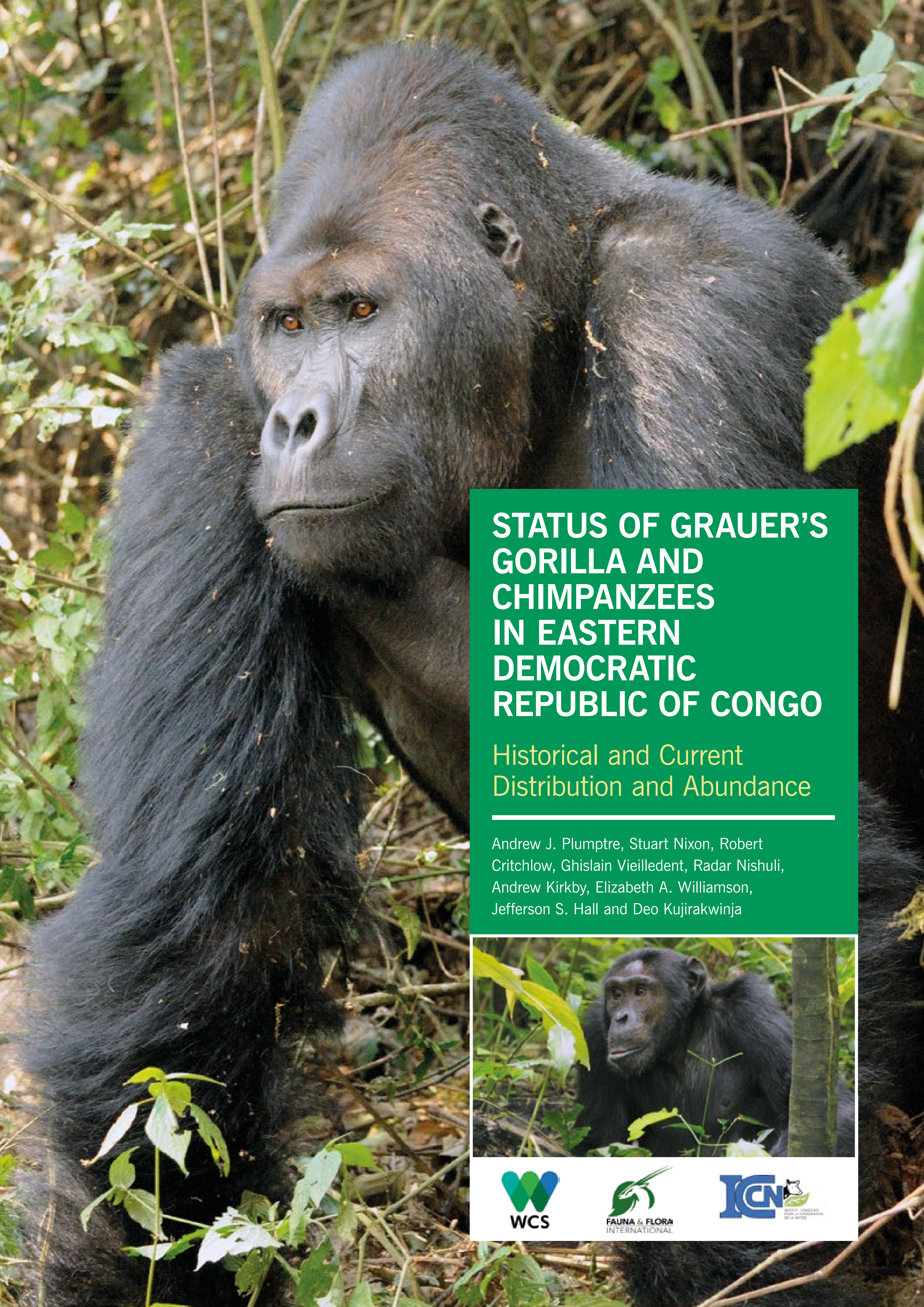

STATUS OF GRAUER'S GORILLA AND CHIMPANZEES IN EASTERN DEMOCRATIC REPUBLIC OF CONGO

Historical and Current Distribution and Abundance

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Front and back cover photos: A.Plumptre/WCS

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ISBN 10: 0-9792418-5-5
ISBN 13: 978-0-9792418-5-7

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The *Wildlife Conservation Society* (WCS) saves wildlife and wild places worldwide through science, conservation action, education, and inspiring people to value nature. WCS envisions a world where wildlife thrives in healthy lands and seas, valued by societies that embrace and benefit from the diversity and integrity of life on earth. Our goal is to conserve the world's largest wild places in 15 priority regions, home to more than 50% of the world's biodiversity. In the Albertine Rift region of Africa WCS has been supporting conservation since 1957 and is the oldest International Conservation NGO working here. Our focus has been on building the capacity of the protected area authorities in the region to be able to better manage their protected areas as well as providing results of scientific research to better understand the importance of the Albertine Rift and how best to conserve the incredibly rich biodiversity to be found here. Find more at: www.albertinerift.org, www.wcsuganda.org, and www.wcs.org

Established over a century ago, *Fauna & Flora International* (FFI) was the world's first international conservation organisation. It is renowned for its innovative, landmark programmes, many of which have come to be regarded as classic examples of conservation practice .The pioneering work of its founders in Africa led to the creation of numerous protected areas, including Kruger and Serengeti National Parks. Today Fauna & Flora International's work spans across the globe, with over 140 projects in over 40 countries, mostly in the developing world. FFI proudly stands up for biodiversity and aims to show just how relevant it is to all of those who share the planet. FFI has supported Great Ape conservation in DRC since 1991 with the creation of the collaborative International Gorilla Conservation Programme which helps protect the Critically Endangered mountain gorillas of DRC, Rwanda and Uganda. In 2009 FFI started community conservation programmes around the Maiko and Kahuzi-Biega national parks in support of ICCN, and since this time has worked with rural communities to reduce forest exploitation, conducted participatory biodiversity surveys throughout the landscape, provided capacity-building programmes for DRC nationals in ape monitoring techniques, and developed community-based ape monitoring programmes around the Maiko National Park. Find out more at: www.fauna-flora.org

The *Institut Congolais pour la Conservation de la Nature* (ICCN) has a mission to assure the protection of the fauna and flora in the network of protected areas of the Democratic Republic of Congo, to encourage research and tourism and to manage stations for capture and domestication of wild animals. ICCN manages five World Heritage sites including the Virunga National Park, Africa's oldest park, and the Kahuzi-Biega National Park which conserves a large proportion of the endangered Grauer's gorilla population. For more information: www.iccn.cd

Citation: Plumptre, A.J., Nixon, S., Critchlow, R., Vieilledent, G., Nishuli, R., Kirkby, A., Williamson, E.A., Hall, J.S. & Kujirakwinja, D. (2015). *Status of Grauer's gorilla and chimpanzees in eastern Democratic Republic of Congo: Historical and current distribution and abundance.* Unpublished report to Arcus Foundation, USAID and US Fish and Wildlife Service.

EXECUTIVE SUMMARY

This report summarises the current state of knowledge on the distribution, densities and trends in abundance of Grauer's gorilla (*Gorilla beringei graueri*) and the eastern chimpanzee (*Pan troglodytes schweinfurthii*) in eastern Democratic Republic of Congo (DRC). It summarises the historical knowledge about the distribution of Grauer's gorilla across its range and describes the development of a Conservation Action Plan (CAP) for these two ape species. A result of this CAP was funding from Arcus Foundation, KfW, USAID, UNESCO and US Fish and Wildlife Service to undertake an assessment of the current status of these apes across the range of Grauer's gorilla. Wildlife Conservation Society (WCS) and Fauna & Flora International (FFI) worked with Institut Congolais pour la Conservation de la Nature (ICCN) and the Reserve managers of the Reserve des Gorilles de Punia (RGPU) and local communities to undertake surveys across the region using a variety of methods: line transects, recces along paths and patrol data from data collected by rangers while on patrol and entered into SMART software.

This survey region has been characterised by insecurity and lawlessness since the start of the Congolese civil war in 1996. Many militia groups have controlled different areas and established artisanal mining camps to fund their operations. Most of these mining camps rely on access to bushmeat for the miners to survive and great apes are among the more highly prized species because of their relatively large size.

Results show a major decline in both species of ape across this region with an estimated 84–93% decline in Grauer's gorilla across its range and between a 22 and 45% decline in the eastern chimpanzee populations. In the case of Grauer's gorilla, an 80% decline in 20 years is justification for listing this subspecies as Critically Endangered on the IUCN Red List of Threatened Species (IUCN 2015). The eastern chimpanzee is more widespread, occurring across northern and eastern DRC as well as in Central African Republic, Uganda, Rwanda, Burundi, western Tanzania and western South Sudan, and may not be as threatened across its range but given the decline in this part of DRC it should be monitored more closely.

Using an occupancy analysis and the True Skills Statistic (TSS) to identify a threshold occupancy probability we estimate the area where each ape is likely to occur in the landscape. Using measures of average density from across the landscape we estimate that only 2,585 (95% confidence limits: 1,802–4,528) Grauer's gorillas remain in the wild across their range, and about 37,740 (95% confidence limits: 14,019–67,196) chimpanzees in this landscape.

GREAT APES IN EASTERN DEMOCRATIC REPUBLIC OF CONGO

Infant Grauer's gorilla, Kahuzi-Biega National Park. *Credit A. Plumptre/WCS*

This report summarises the current knowledge about the status of Grauer's gorilla (*Gorilla beringei graueri*) throughout its range and of the eastern chimpanzee (*Pan troglodytes schweinfurthii*) in the eastern Democratic Republic of Congo (DRC). The area of focus is as defined in the *Conservation Action Plan for Great Apes in eastern DRC* (Maldonado *et al.* 2012), which encompasses the Maiko National Park in the north down to the Kabobo massif in the south and the border of DRC in the east to the Lualaba River in the west. The forests of eastern DRC are one of the most globally important regions for biodiversity. Within this region lies the entire range of the endemic Grauer's gorilla (Fig. 1). Grauer's gorilla is currently classified as Endangered (A4abcd) on the IUCN Red List (Robbins & Williamson, 2008), is listed on Appendix I of CITES and has full legal protection under DRC law. The eastern chimpanzee (chimpanzee henceforth) is also classified as Endangered (A4cd) on the IUCN Red List (Wilson *et al.* 2008) and occurs throughout the area of focus in both forests and woodland habitats. This report summarises the historical information known about these great apes in eastern DRC and provides measures of occupancy probability and changes in abundance in certain areas where these have been measured to provide the best estimate to date of the status.

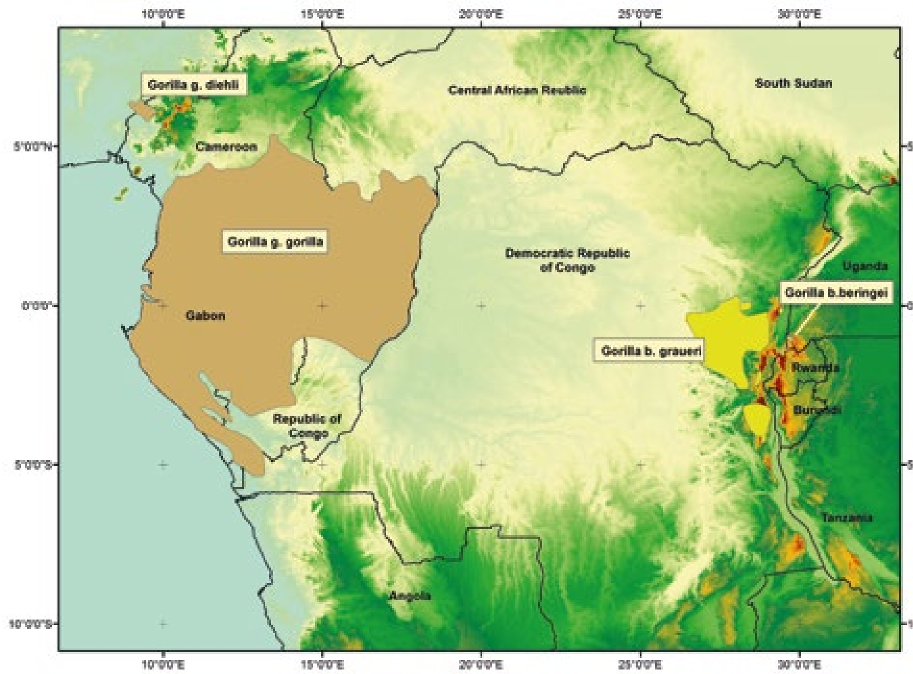


Figure 1. Distribution of Grauer's gorilla in relation to other gorilla subspecies. Background map is elevation from light green (low) to dark brown (high)

Grauer's gorilla is in severe crisis. Agricultural and pastoral expansion, high levels of subsistence hunting and bushmeat extraction, the exotic animal trade, extensive mining and socio-economic depression from over a decade of civil war place tremendous pressure on DRC's forest resources and fauna. Since 1996, the entire range of Grauer's gorilla has been consumed in conflict. This has resulted in an almost complete breakdown of government control, including wildlife protection activities. Important populations of this gorilla subspecies and their relatives, chimpanzees, have gone unmonitored for years and, as a result, the current status of Grauer's gorilla has been poorly known since surveys made by the Wildlife Conservation Society (WCS) between 1992 and 1995 (Hall *et al.* 1998a).

Conservation challenges are likely to increase as DRC continues to stabilize. Security will bring further development of extractive industries, infrastructure and large-scale agriculture. While this will increase DRC's ability to support itself and participate in the global economy, it is likely to result in increased settlement in forests around protected areas, including those critical for gorillas. Targeted action as well as prioritization of specific conservation areas will be vital to slow the decline of species like gorillas and chimpanzees. Failure could mean the extinction of Grauer's gorilla and other important and threatened species within the next few decades. Furthermore, the absence of a viable ex situ population means that all conservation efforts must focus on wild populations.

CONSERVATION ACTION PLAN FOR GREAT APES

In 2011, the Jane Goodall Institute (JGI) took the lead in an effort, at the request of ICCN and the Ministry of the Environment, to develop a participatory Conservation Action Plan (CAP). The CAP, facilitated by JGI with support from Arcus and the World We Want Foundation, brought together 104 representatives from 11 organizations, including scientists, local, regional and national government agencies, and local and international NGOs including the IUCN SSC Primate Specialist Group. Experts participating in the CAP, upon review of available data and anecdotal evidence, tentatively estimated that the total Grauer's gorilla population might now be as low as 2,000–10,000 individuals (Nixon *et al.* 2012). They also identified a landscape boundary (Fig. 2).

A primary recommendation emerging from the CAP process was the urgent need for fieldwork to establish the true Status of Grauer's gorilla and chimpanzees in eastern Democratic Republic of Congos across the area of focus (Fig. 3), and to identify priority populations on which to focus conservation action. Further engagement with communities

Bamboo forest Kahuzi-Biega National Park, highland sector. *Credit A. Plumptre/WCS* was also prioritized, although it was agreed that such activities must target the highest priority ape populations. Thus, a thorough field assessment of gorilla and chimpanzee populations and socio-economic conditions in key regions of their range was a research priority for both landscape-level conservation planning and localized conservation projects. The process and development of the CAP has provided an invaluable platform for the conservation and government agencies in the region to base their activities and strategies. It enabled a compilation of the existing data on great ape distribution in the region and sharing of data that has continued to the present day.

HISTORICAL DISTRIBUTION OF GRAUER'S GORILLA

Data used in this preliminary assessment were provided to the Jane Goodall institute for the CAP process by the Wildlife Conservation Society, Fauna & Flora International, Conservation International, Dian Fossey Gorilla Fund International, The Gorilla Organization, UGADEC and affiliated reserves, and ICCN. Additional data were kindly provided by the Walikale Gorilla Reserve and Dr. George Schaller. A complete multi-authored status report is in preparation, however a corresponding paper "The Forgotten Gorilla: Historic perspectives and future challenges

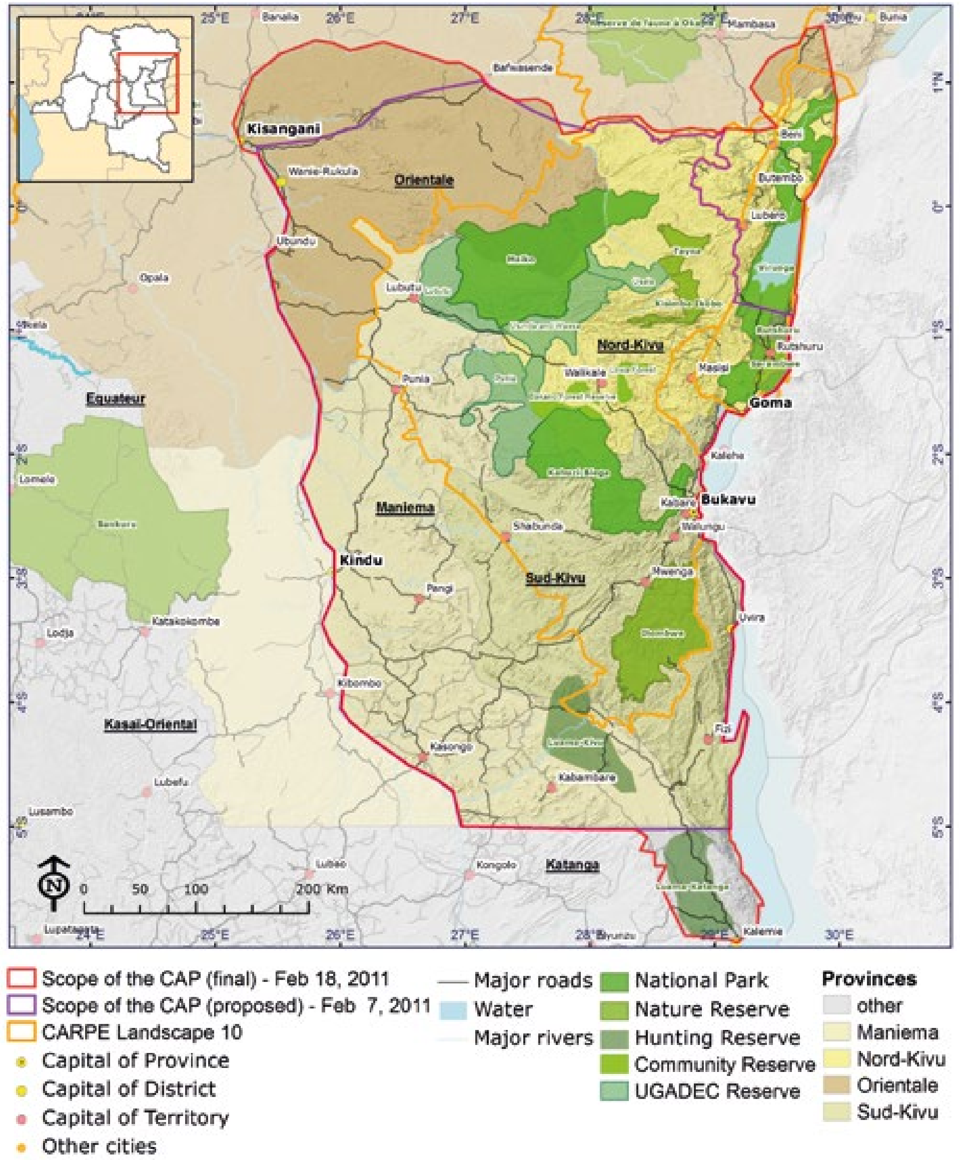


Figure 2. Area of focus for the Conservation Action Plan: the CAP Landscape

Young eastern chimpanzees grooming. *Credit A. Plumptre/WCS*

for conserving Grauer's gorilla" (Nixon *et al.* 2012) was presented at the International Primatological Society Congress in Cancun, Mexico, in August 2012. A summary of our findings is presented below.

DISTRIBUTION

Grauer's gorilla's historic range is encompassed within an area of approximately 52,000 km^2 (Mehlman 2008), from the Albertine Rift escarpment in the east towards Punia in the west, and from the Lindi River in the north to the Itombwe massif in the south. Currently, four broadly-defined population centres are recognized: Maiko (including Maiko National Park and adjacent forests, Tayna-Usala (including Tayna Nature Reserve, Kisimba-Ikobo Nature Reserve and the Usala forest), Kahuzi-Kasese (including Kahuzi-Biega National Park (KBNP) lowland sector and adjacent forest to the west in the Reserve des Gorilles de Punia), and the Itombwe Massif (including Itombwe Natural Reserve). Additional isolated populations are found in Masisi and the Kahuzi-Biega National Park highland sector, and on Mt. Tshiaberimu in Virunga National Park (Fig. 4). Gorillas also ranged south of Itombwe in the bamboo forests of the western rift escarpment and a WCS survey found signs of a few remaining here in 2014, but they were being hunted. All of the protected areas in which Grauer's gorillas are found were created specifically or in part to protect this subspecies, with Kahuzi-Biega and Maiko National Parks considered to support the most important populations.

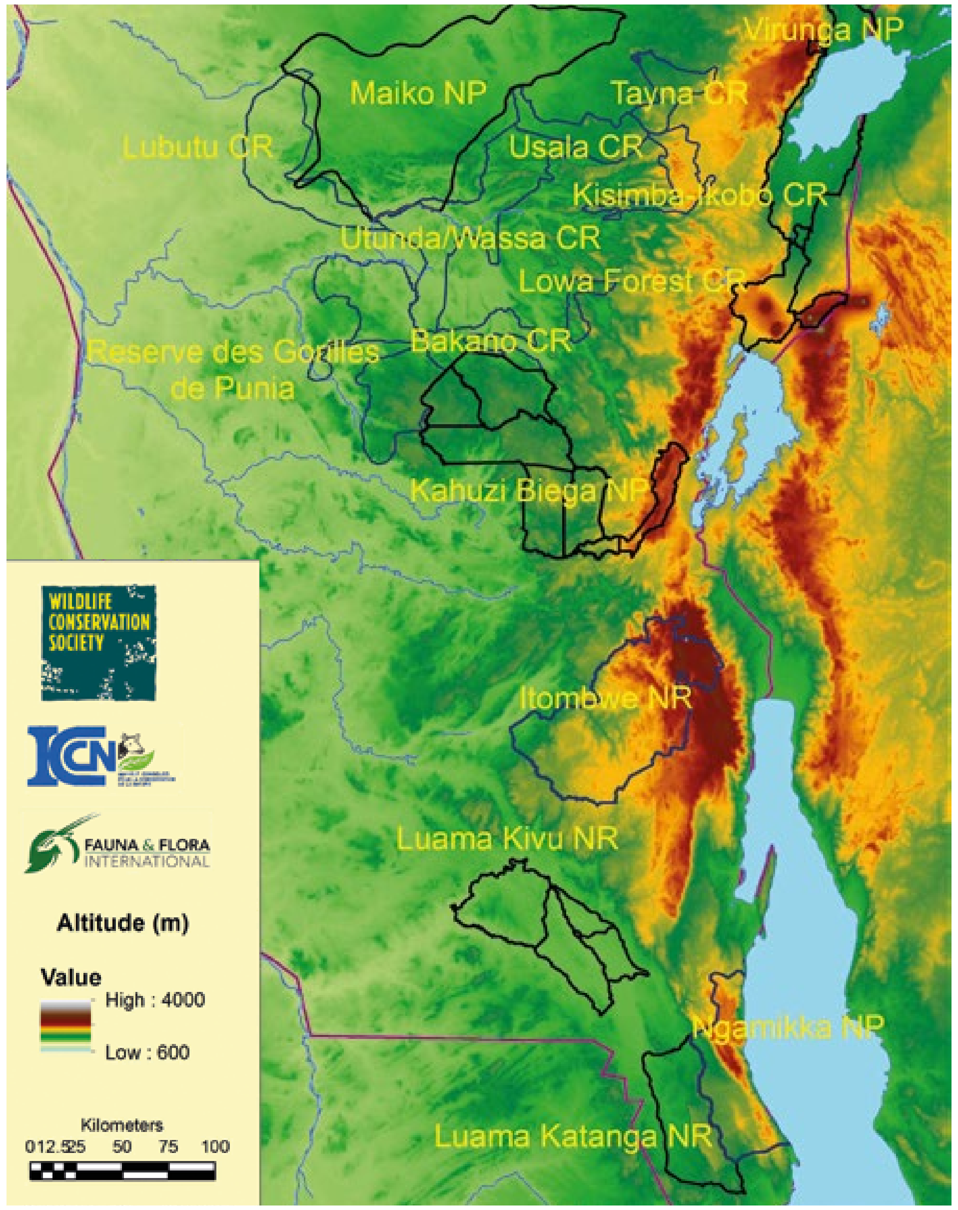
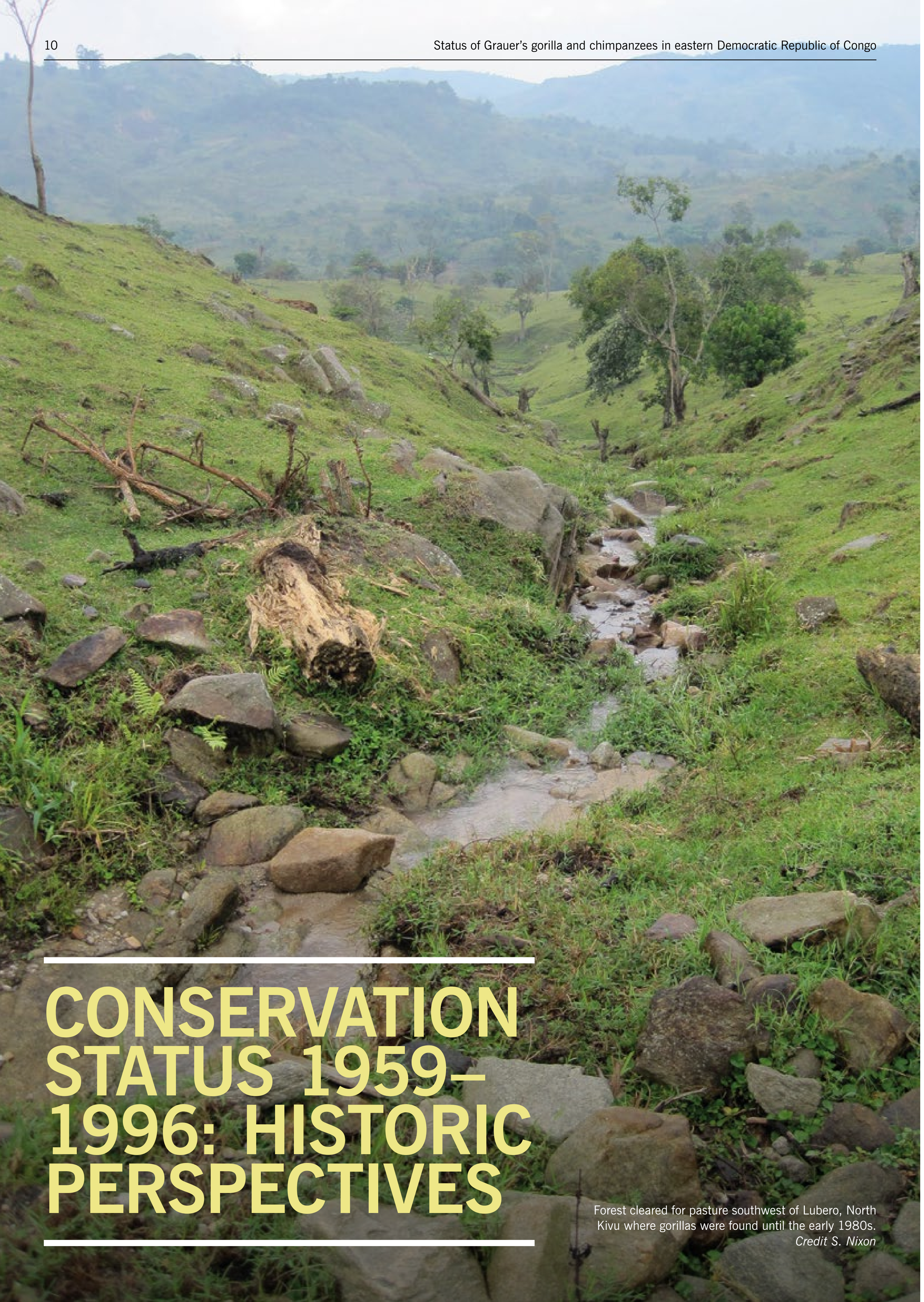


Figure 3. Location of protected areas referred to in this report. Those indicated with a black boundary are legally protected areas. Blue-bounded protected areas are community reserves or proposed protected areas. Many of these community reserves are in the process of being established and their boundaries are likely to change as this takes place.

Lowland rainforest, Maiko National Park. *Credit S. Nixon*



CONSERVATION STATUS 1959–1996: HISTORIC PERSPECTIVES

Forest cleared for pasture southwest of Lubero, North Kivu where gorillas were found until the early 1980s. *Credit S. Nixon*

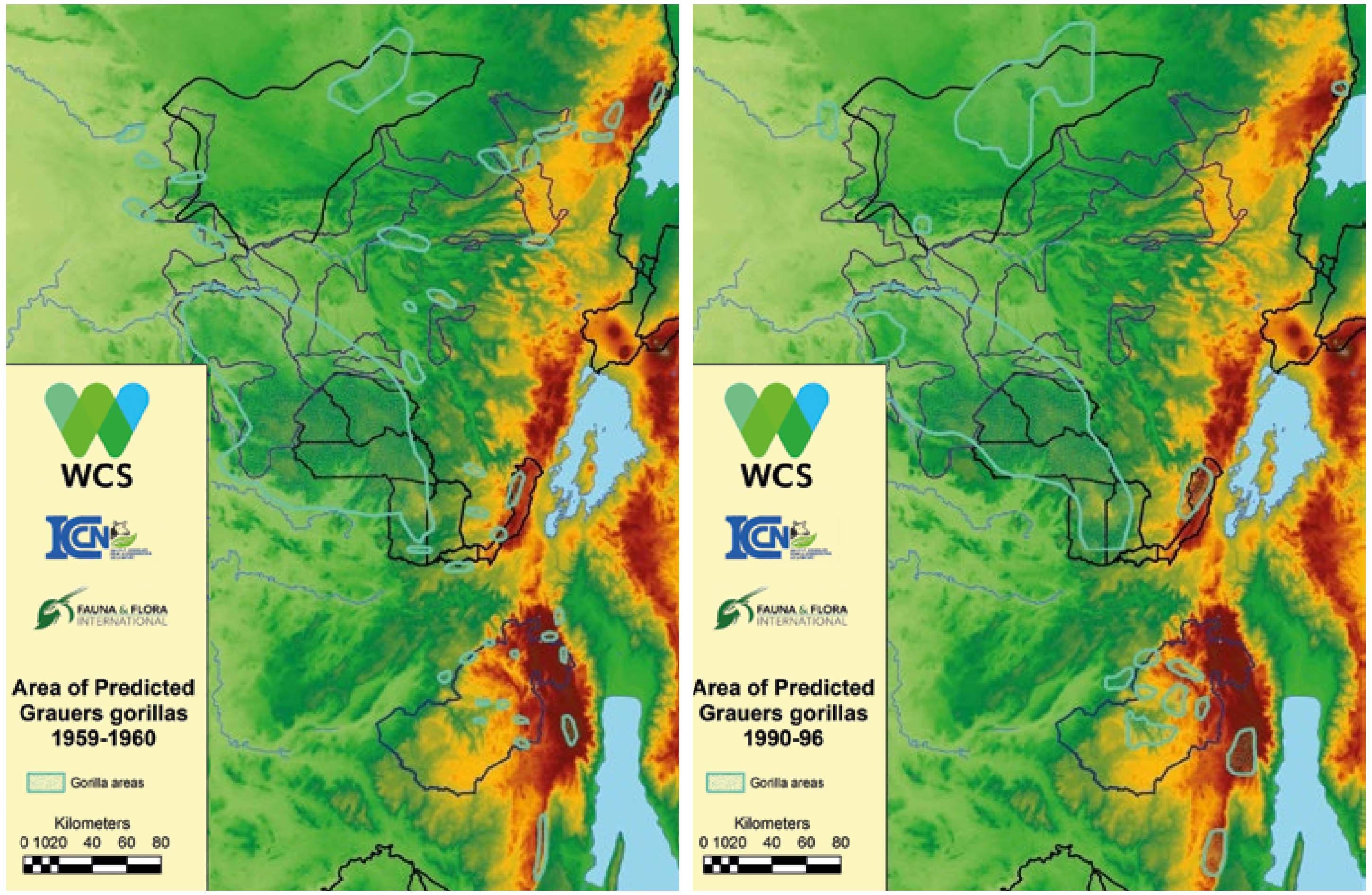


Figure 4. Distribution of Grauer's gorilla from Emlen and Schaller's surveys (left) and Hall *et al.*'s surveys (Right). *Distribution layer by S. Nixon and L. Pintea (Jane Goodall Institute)*

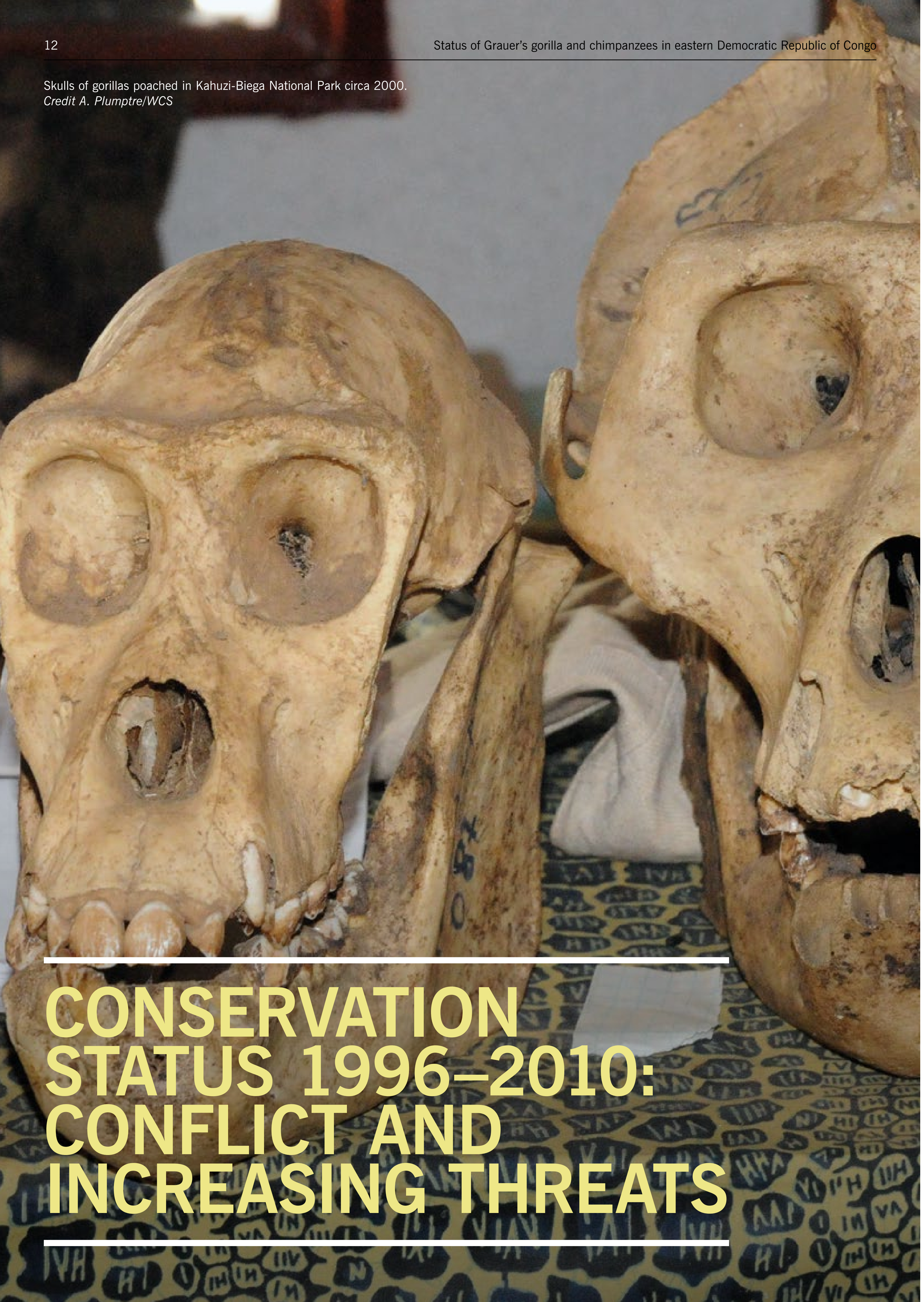
The first surveys of this subspecies (then grouped with the Virunga and Bwindi populations as mountain gorillas) by Emlen and Schaller in 1959 documented that, west of the Albertine Rift, gorillas occurred at low overall density with a highly fragmented and patchy distribution (Fig. 4). High densities were found only in small, localized subpopulations, while large areas of contiguous and seemingly suitable habitats were unoccupied (Emlen & Schaller 1960). They concluded that gorillas were rare and likely undergoing a rapid population decline due to habitat conversion in the highland regions and widespread hunting in retaliation for crop raiding and, opportunistically, for meat. Based on limited data, they broadly estimated the existence of between 5,000 and 15,000 individuals (Emlen & Schaller 1960; Schaller 1963).

During the 1960s and 1970s, a significant percentage of the gorilla's Afromontane habitat in the Kivus was converted to pasture and agricultural land. A concurrent proliferation of 12-gauge shotguns, promoted by the then-Zaïrian government, facilitated the hunting of large mammals such as gorilla, resulting in their local extinction in many areas (P. Anderson pers. comm. 2010).

50,000 Zaire note in circulation until the mid-1990s featuring Maheshe, a habituated gorilla in Kahuzi-Biega National Park. *Credit S. Nixon*

Subsequent surveys did not take place until the 1990s and focused on KBNP and adjacent Kasese forest (Hall *et al.* 1998b; Yamagiwa *et al*. 1993), Itombwe (Omari *et al*. 1999) and Maiko National Park (Hart & Sikubwabo 1994). These surveys found that gorillas remained highly threatened, primarily by hunting and expanding human settlements. The loss of several subpopulations in Itombwe was documented, as was a range reduction in the Kahuzi-Kasese region. From these surveys, Hall *et al.* (1998a) estimated a total population of 16,900 (8,660–25,500) individual gorillas. However, the North Kivu region (Tayna, Usala, Kisimba-Ikobo, etc.) was largely omitted from the assessment due to a lack of data. This broad abundance estimate overlaps and considerably increases that previously estimated by Emlen and Schaller, despite a considerable amount of habitat loss and several localized extinctions having been recorded since 1959. The wide estimates calculated from both studies illustrate the difficulties associated with calculating accurate abundance estimates for Grauer's gorilla from one-off surveys. Prior to the 1990s surveys even less was known about the status of chimpanzees in the region, with the 1994–95 KBNP surveys representing the first systematic effort to census this species. These surveys also estimated the numbers of chimpanzees in the KBNP and the Kasese region to the west of the park at 2,600 weaned individuals, 2000 in the park and 600 in the Kasese region.

Firewood collection from the forest. *Credit E. Williamson*



Skulls of gorillas poached in Kahuzi-Biega National Park circa 2000.
Credit A. Plumptre/WCS

CONSERVATION STATUS 1996–2010: CONFLICT AND INCREASING THREATS

Threats to gorillas identified between 1959 and 1996 were massively exacerbated throughout the late 1990s and early 2000s with the onset of fierce conflict in the Great Lakes region. In 1994, hundreds of thousands of refugees fled into DRC following the Rwandan civil war and genocide, settling in forest areas throughout the east, including KBNP. This destabilized the already fragile Zaïrian government, plunging the country into civil war and humanitarian crisis. Refugees, internally displaced people and numerous armed groups placed enormous pressure on DRC's forests through uncontrolled hunting, harvesting of wood for fuel, habitat conversion for farmland, timber extraction and mining. Since 1996 two civil wars have raged in eastern DRC and although the war ended officially in 2003, unregulated extraction of gold, tin (cassiterite), tungsten, diamond and coltan (a highly valued metal used in the manufacture of mobile telephones and computer equipment) continues to fuel civil conflict (United Nations 2010). High levels of insecurity and poor accessibility to remote regions throughout the 1990s and 2000s have prevented a coordinated, range-wide effort to assess the status of Grauer's gorilla, though preliminary work has been possible in some areas. Results from these surveys indicated that the subspecies is likely to be in severe decline across most of its range.

A dilapidated road network work hinders accessibility throughout much of rural eastern DRC.
Credit S. Nixon

S. Nixon and local farmer inspect gorilla crop-raiding damage, Byakili, Tayna

In 2008, it was estimated that approximately 25% of Grauer's gorilla habitat first identified by Schaller had been lost in the Albertine Rift highlands, reducing its extent to 21,600 km^2 (Mehlman 2008). In KBNP, the highland population decreased by 50% between 1996 and 2000 (Wildlife Conservation Society 2000). Although much of the lowland sector of the KBNP remains insecure, surveys have indicated an alarming decline in nest encounter rates of 75–85% since the mid 1990s; however, it was not possible to survey the same areas as surveyed by Hall *et al.* (1998) due to insecurity making comparisons difficult. Similarly, surveys in the Itombwe massif have documented a 50% reduction in gorilla group size since 1996, the localized extinction of two subpopulations and rapidly increasing habitat fragmentation from mining and settlement (WCS unpublished data).

The status of the Maiko National Park populations is precarious; the southern populations exist in a region occupied by Simba rebels and the status of the northern population, centred at Ogombu, remains completely unknown since 1994 due to a lack of park infrastructure and the presence of rebel militia. Hunting of gorillas in the southern sector of Maiko National Park has been recorded (Nixon 2006) and at least one sub-population on the north bank of the Lowa River, near Maiko National Park, has been exterminated since it was first documented in 2005 (Nixon 2010).

In North Kivu, the extermination of at least one remnant Masisi population has been reported (C. Aveling pers. comm. 2011), reports exist of military, rebels and civilians hunting gorillas in Walikale Territory, and several gorillas were killed (and an infant captured) in the Tayna Nature Reserve between 2004 and 2007 (Nixon unpublished). The remnant population found on Mt. Tshiaberimu in Virunga National Park exists in a perilous situation. Numbering just six individuals and isolated from other gorilla populations in a 60-km^2 island of montane forest, it remains highly threatened by deforestation and low genetic viability (Sikubwabo 2015). The Kisimba-Ikobo population has yet to be surveyed; however, gorilla hunting and the illegal capture of infants have been recorded from the Pinga region (S. Nixon pers. obs. 2005). A young gorilla was confiscated from Pinga in 2005 by ICCN.

Since 2003, ICCN and its partners have confiscated 15 infant Grauer's gorillas from military and civil society. As casualties of illegal hunting, these individuals are housed in the Gorilla Rehabilitation and Conservation Education (GRACE) Centre near Kasugho, North Kivu. Possible future reintroduction of these confiscated individuals to sites such as Mt. Tshiaberimu offers some hope for small yet isolated subpopulations in well-protected areas.

Orphaned chimpanzee Lubutu, 2005.
Credit S. Nixon

CONSERVATION STATUS 2012: CURRENT 'BEST GUESS' ABUNDANCE

From the data compiled by the partners at the CAP, we identified 14 "known" subpopulations in four priority regions over a geographic range of approximately 33,200 km^2 (Fig. 4 and Table 1). Within this range, the extent of occurrence is currently estimated at approximately 19,000 km^2. However, even within this range, populations are highly fragmented. Therefore, the "true" extent of occurrence is likely to be even less than calculated in Table 1.

Given the gaps in our knowledge, it has been difficult to produce a reliable estimate of the global population of Grauer's gorilla. Using 1990s abundance estimates as a baseline (where applicable), transformed "recce"

Table 1. Tentative "best guess" abundance estimates for Grauer's gorilla, 2011–2012

Site	Area (km2)	Estimated Occupancy 2011 (km2)	Population estimate 2012 (weaned individuals)	Source and measure
Itombwe	10,000	1,400	100–415 (best guess)	Recce walks, WCS data
Kahuzi-Biega NP lowlands	5,400	5,400	1,272–2,518	Recce walks, WCS data, Amsini et al. 2008
Kahuzi-Biega NP highlands	600	260	170	Total count, Amsini et al. 2008
Kasese	7,723	7,723	433–844 (best guess)	UGADEC unpubl. data, Mehlman 2008
Kisimba-Ikobo	963	550	100–350 (best guess)	Presence confirmed, but no survey data
Lowa-Oso	?	N/A	~40 in 2005; presumed extinct in 2010	Recce walks, Nixon/FFI 2010
Maiko NP north	3,200	2,100	111–417 (best guess)	ICCN unpubl. data; local informants, but no survey data
Maiko NP south	1,600	875	306–866	Recce walks, Nixon et al. 2005, Nixon 2010
Masisi	N/A	N/A	Presumed extinct (habitat destroyed)	Kasuku, pers. comm., 2012
North Lowa	?	?	confirmed presence in 1994; presumed extinct in 2012	UGADEC, S.Nixon, pers. comm., 2012
Tayna Gorilla Reserve	906	210	185–210	Monitoring data, transects, partial count, Nixon & Buckley 2006, Nixon unpubl. data
Mt. Tshiaberimu, Virunga NP	40	40	6–14	Total count, ICCN unpubl. data 2012
Usala Forest	1,160	344	240–412	Recce walks, Nixon et al. 2007
Walikale north (Bukonde, Hunde, Utunda)	700	?	150–780	Monitoring data, Recce walks, UGADEC unpubl. data
Walikale east (Bakano)	987	Presence confirmed	25–50	UGADEC unpubl. data
Total	**33,289**	**18,912**	**3,098–7,017**	

encounter rates (after Hall *et al.* 1998) from surveys in areas not covered in the previous range wide assessment, and local reports on un-surveyed populations, a tentative estimate of approximately 3,000–7,000 weaned Grauer's gorillas was made in 2012. This estimate was based on upper and lower limits that reflect an overall calculated decline of 50–75% since 1996 (Nixon *et al.* 2012).

The CAP highlighted the need to survey Grauer's gorilla and chimpanzees across the range of focus, although priority was given to Grauer's gorilla, which is more threatened and occurs only in eastern DRC. The Arcus Foundation expressed interest in supporting surveys of the region and at the CAP it was agreed that several NGOs would take the lead in carrying out surveys in different parts of the range of these apes. Over the past three years, these NGOs have undertaken surveys of the respective regions allocated. WCS has also been supporting a system of Law Enforcement Monitoring (LEM) in the national parks, faunal reserves and community reserves that exist in the landscape. These have provided additional data on locations of sightings of chimpanzees and gorillas that have been entered into SMART (the Spatial Monitoring and Reporting Tool). Financial support for this work has come from Critical Ecosystem Partnership Fund, KFW, Rainforest Trust, UNESCO, USAID, USFWS and World Bank.

THREATS TO GREAT APES IN EASTERN DRC

Bushmeat trader with an owl-faced monkey (Cercopithecus hamlyni)a protected speciesnear Lubutu, Maniema. *Credit S. Nixon*

Local bushmeat hunters, Okoku, Maniema. *Credit S. Nixon*

Both chimpanzees and gorillas are primarily threatened by bushmeat hunting practices in eastern DRC. While a trade in infants exists, it is usually a result of the obtaining of an infant once its mother has been killed (often opportunistically) for its meat. Habitat loss is also a key threat, as agriculture spreads out from the edges of the forest in the east and along major roads through the forest.

Artisanal mining is a major source of threat to apes because miners move deep into the forest to access potential mine sites and once there rely on bushmeat hunting to feed themselves. Apes are also at risk from disease transmission from miners due to the unsanitary condition typical of these sites. Because of the potential mineral wealth, many mines are controlled by armed militias making hunting of wildlife easier. In order to halt the decline in great ape populations, Arcus Foundation and USAID supported WCS to conduct a study of mining sites around protected areas in DRC and their impacts on great ape populations (Kirkby *et al.* 2015). Data from 40 mine sites and over 700 respondents found the continued presence of mining in the region (within and around the protected areas), sustaining large numbers of people who are exploiting cassiterite, gold, coltan and wolframite (in order of most exploited to least). None of these mines are legally registered with the government. Most mines were controlled by armed groups with mainly seasonal workers from an array of professional and social classes. Miners were attracted by quick money and earned on average 116 USD per month, with those controlling mines gaining revenues up to 1,000 USD per month. The study found that mining has negative impacts in KBNP and Itombwe Reserve, particularly threatening endangered species through poaching. Bushmeat hunting occurred at almost all sites – both inside and outside protected areas throughout the year – with individuals in mining communities openly stating that they consumed bushmeat. Most hunting was indiscriminate of species; however, the most hunted groups of species included porcupines, Gambian rats, duikers and primates. Many said that chimps, gorillas and elephants had disappeared in recent years due to bushmeat hunting and habitat destruction. However, 27% of respondents were aware of great apes still existing near mine sites, which emphasises the importance of protecting great apes near these sites.

In order to ensure the protection of great apes and protected wildlife, the study strongly recommended the disarming of miners to allow eco-guards to enforce environmental laws as well as helping to expand patrol coverage to prevent the development of new mines. Both miners and non-miners were open to the idea of stopping hunting if alternative meats were available – therefore helping to improve the supply of alternative meats around legal mines should be a priority. Many miners were keen to leave the mining sector for alternative economic activities, so another option is to make agriculture more profitable and attractive through the development of high value crops such as coffee, micro-loans, and improving farming systems and knowledge to increase crop productivity and value (Kirkby *et al.* 2015).

Habitat loss is a lesser threat in the region at the moment, although the expansion of road systems and improvement of the roads is leading to settlement and the loss of connectivity between ape populations as a result.

Both distance to mine sites and distance to roads and villages were used in the occupancy modelling (below) to predict the probability of ape occurrence across the region.

Forests recently felled for agriculture, Usala. *Credit S. Nixon*

FFI field assistant Magloire Vyalengerera with artisanal miners west of Maiko National Park. *Credit M. Vyalengerera*

METHODS

Deo Kujirakwinja, WCS, trains survey teams in census techniques.
Credit A. Plumptre/WCS

As part of the pre-survey coordination and in order to address the problems associated with current survey techniques available for great apes, a major objective of this project was to coordinate the development of a standardized approach to surveying and monitoring great apes that was both scientifically sound and adapted to the local context in eastern DRC.
A number of techniques are currently used for assessing gorilla distribution, abundance and threats (Kühl *et al.* 2008). For large forest blocks, reconnaissance walks are used to assess distribution and calculate the relative abundance (sign/km walked) of gorillas and threats. "Recces" are a relatively low cost survey method effective for increasing survey coverage in remote forests. However, the results allow only crude comparisons between sites or over time; they do not generate the population abundance estimates needed to establish baselines for close monitoring of gorilla populations. The Recce method can easily be incorporated into regular monitoring patrols by wildlife authorities or communities to assess trends in encounter rates but is not the most effective method for surveys.
Line transects use distance sampling methods to calculate animal density and ultimately abundance estimates. Counts are made of nests and these are converted to an animal density using correction factors that include the production rate of the nests (usually assumed to be 1 per day) and the decomposition rate of the nests. If resources permit, marked nest counts are undertaken which involve repeated sampling of transects to avoid the necessity of determining site-specific nest decay rates. These density estimates (individuals/km^2) are then extrapolated over survey regions to calculate abundance estimates for target species. While transects produce more accurate and less biased data than recces, they require more time to conduct, require a high level of training and supervision, and are labour intensive. Transect surveys can also be extremely difficult to conduct over rugged terrain. Progress through difficult habitat types can in extreme cases be as little as 1–2 km per day.

For the small, isolated mountain gorilla populations, a total count methodology has been developed. Field teams walk recce lines until gorilla trail or nest sites are found. Teams record the number of nests and group composition to identify the number of gorilla in each nest group located. Teams then attempt to follow the gorilla trail between three consecutive nest sites to further confirm the number of gorillas in each group in a given area. If nest sites from all gorilla groups are located then a total population estimate can be calculated.

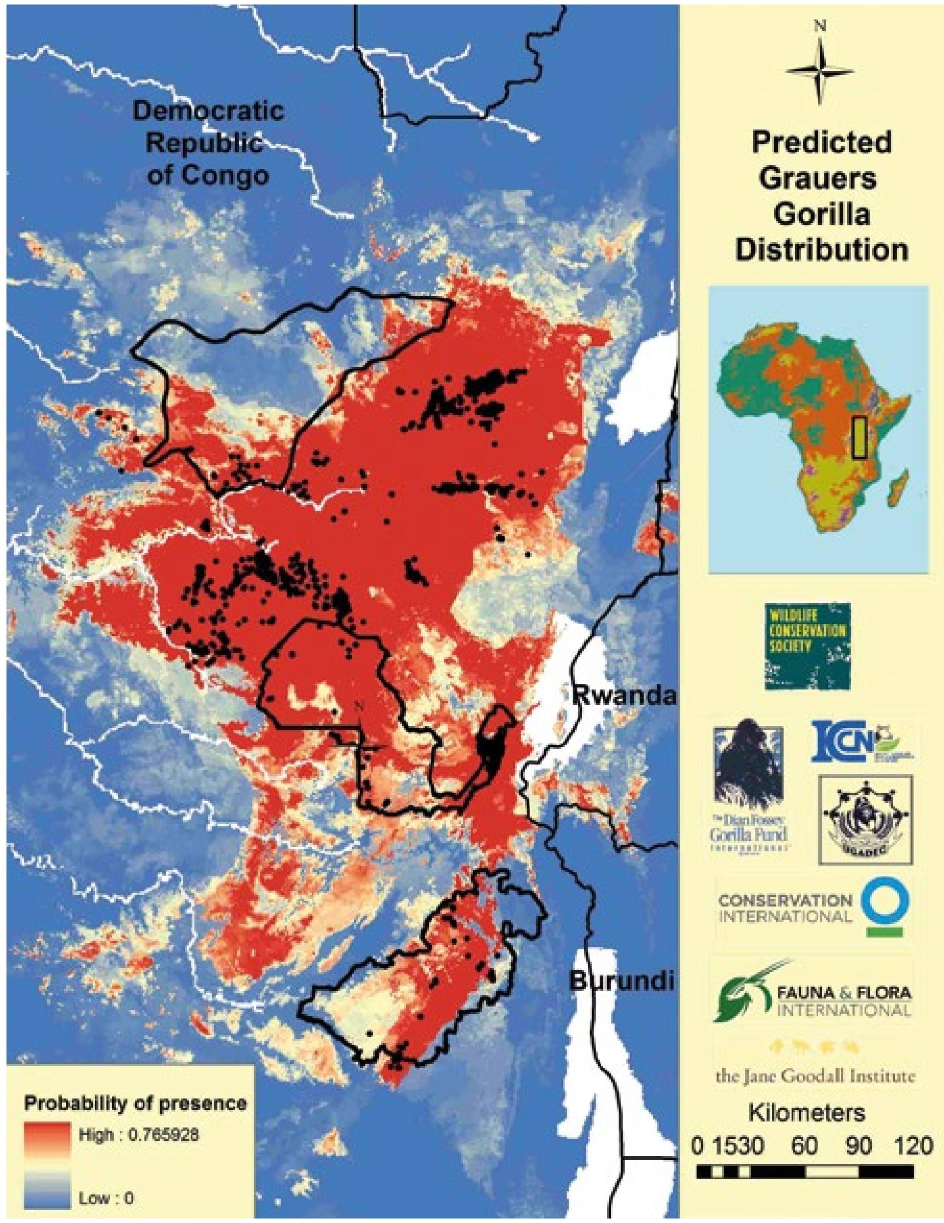


Figure 5. Predictive model of Grauer's gorilla distribution from MAXENT analysis. Black points are gorilla locations used in the model

Grauer's gorilla presents a specific and difficult case. The subspecies occurs in discrete, isolated populations over a relatively large geographic range. Gorilla habitats in eastern DRC are also extremely rugged, remote and often difficult to access. Security and the presence of various rebel groups are also a considerable constraint, limiting access to remote areas.

Faced with the huge challenges associated with eastern DRC, the CAP process recommended that intensive surveys focused on gorilla populations of historic importance should be executed in the near future and baselines established by 2014. As many areas of Grauer's gorilla range remained insecure and operating costs in eastern DRC were high, it was unlikely that surveys would be able to reach every corner of their range. Given the patchy distribution of Grauer's gorilla and high costs in producing high-resolution abundance estimates from one-off transect and recce-based surveys, it was felt that using transect or recce surveys across Grauer's range would be impossible.

A method was developed that aimed to permit an occupancy analysis of the two apes across eastern DRC. This two-stage approach would initially predict where the apes were more likely to be present and, if confirmed, the plan was to undertake more detailed surveys to estimate population numbers at those sites:

Training in use of GPS; ICCN rangers practicing GPS techniques. *Credit A. Plumptre/WCS*

Stage 1: Undertake occupancy surveys of gorilla and other key species in the sites where Grauer's gorillas are known to occur.

Stage 2: Undertake detailed surveys of Grauer's gorilla at sites where fresh trail has been sighted using nest counts and DNA sample collection to enable the population size to be accurately estimated.

In order to develop this method, gorilla presence data collated through the CAP were prepared by S. Nixon and made available to A. Plumptre in July 2012. Dr Plumptre began spatial analysis using the MAXENT software package and several species distribution models were developed. Finally, a threshold model highlighting the most likely occupancy of gorillas in eastern DRC was produced (Fig. 5).

A survey protocol based on the results of the modelling was developed (Plumptre *et al.* 2013) and is summarised here.

OCCUPANCY ANALYSIS

Original plan for surveys

Using data on known locations of Grauer's gorillas, collected through surveys and monitoring by DFGFI, FFI, UGADEC, and WCS during the past 10 years, a species distribution model was produced using MAXENT (Fig. 5). A 5x5 km grid was established along UTM coordinate lines across the whole study area (Fig. 6). This size of cell was chosen because a Grauer's gorilla home range is approximately 25–35 km^2. Ideally, sites where the probability of gorilla presence was highest would be visited to confirm occupancy, but this still left an infeasible number of cells to visit. Selecting only those where the MAXENT suitability was greater than 0.1 resulted in 3,115 cells to survey. Instead, 120 randomly selected cells, weighted by a 25% probability to sample from known Grauer's gorilla areas, were identified and our aim was to walk from one corner of each cell to the opposite corner.

Each 1-km segment of the transect within a cell was to be recorded separately for the occupancy replications and the sightings of chimpanzee and gorilla sign recorded as well as other key species (such as elephant, buffalo, okapi and bongo) were noted on data sheets. The 7–8 1-km segments across the diagonal of the 5x5 km cell were then analysed as

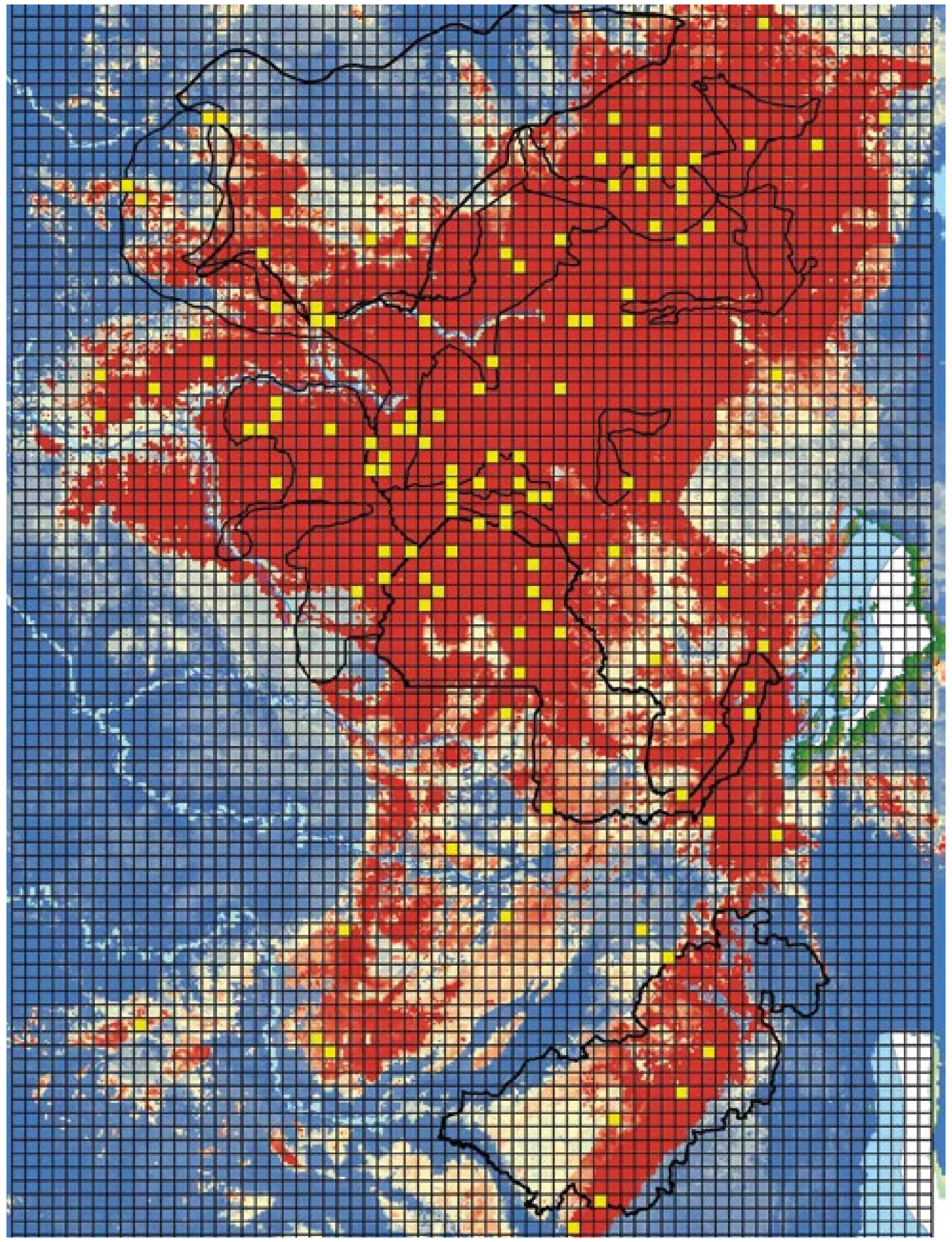


Figure 6. 120 selected cells (yellow) in the Grauer's landscape using the method described above. Cells are overlaid on the probability of occurrence map (Fig. 5)

spatial replicates for the occupancy analysis. Sightings of animals, dung, nests, and footprints were used to validate occupancy provided they were clearly distinguishable.

Final method used

Insecurity in the region made it very difficult to access the 120 cells as planned, particularly in the north around Maiko National Park, Tayna and Kisimba-Ikobo Nature Reserves and the Usala region (including the developing Usala Community Reserve). As a result, we investigated other data sources we could use for the occupancy analysis. WCS introduced SMART software to store and analyse data collected for law enforcement monitoring, usually by rangers on patrol in protected areas. WCS not only established SMART databases in ICCN-managed protected areas but also in the community-managed regions of RGPU and Itombwe Reserve. Consequently, the available data covered a significant portion of the landscape when combined with other WCS surveys as well as the occupancy data from the cells WCS and FFI had managed to reach (Fig. 7).

We used these data to calculate occupancy estimates for each of the 5x5 km cells across the landscape in the following way. Each dataset consisted of point data with GPS coordinates. The points were linked with lines for each patrol/survey to produce tracks of where teams had passed. These were then cut into cell-segments for each 5x5 km cell across the landscape to obtain the length of track in each cell. These cell-segments were then divided into 1-km units and the presence of gorilla or chimp sign noted for each 1-km unit in each cell. Only track lengths of 1 km were used (shorter sections were excluded). These 1-km units were used as replicates for the occupancy analysis to estimate detection probability in cells where surveys included more than one unit. The number of units ranged from two to 50 per cell.

The occupancy analysis was performed using the R-package hSDM (Vieilledent *et al.* 2014). This package uses a Bayesian hierarchical approach that can incorporate spatial dependency in the analysis while estimating occupancy. When trying to estimate occupancy of the 5x5 km cells across the landscape, two issues need to be considered: 1) imperfect detection and 2) spatial correlation. When a team visits a cell and walks through it they can either detect sign of gorillas or they do not. If they do not, it may be because the gorillas were truly not there (true absence) or because they were missed but actually were there (false absence). Occupancy analysis enables an estimate of the detection probability to be made, which is usually less than 1 because in most surveys some animals are missed. A hierarchical or mixture model approach is used to estimate detectability and Bayesian statistical methods are very useful tools when it comes to estimating the parameters of such complex models. Spatial correlation is important because most species show some form of geographical patchiness. For example, if the species is present at one site, it is more likely that the species is also present at neighbouring sites, whatever the environmental conditions. Also, given the non-random nature of the sampling we made here it was important to factor in the geographical patchiness in our analyses.

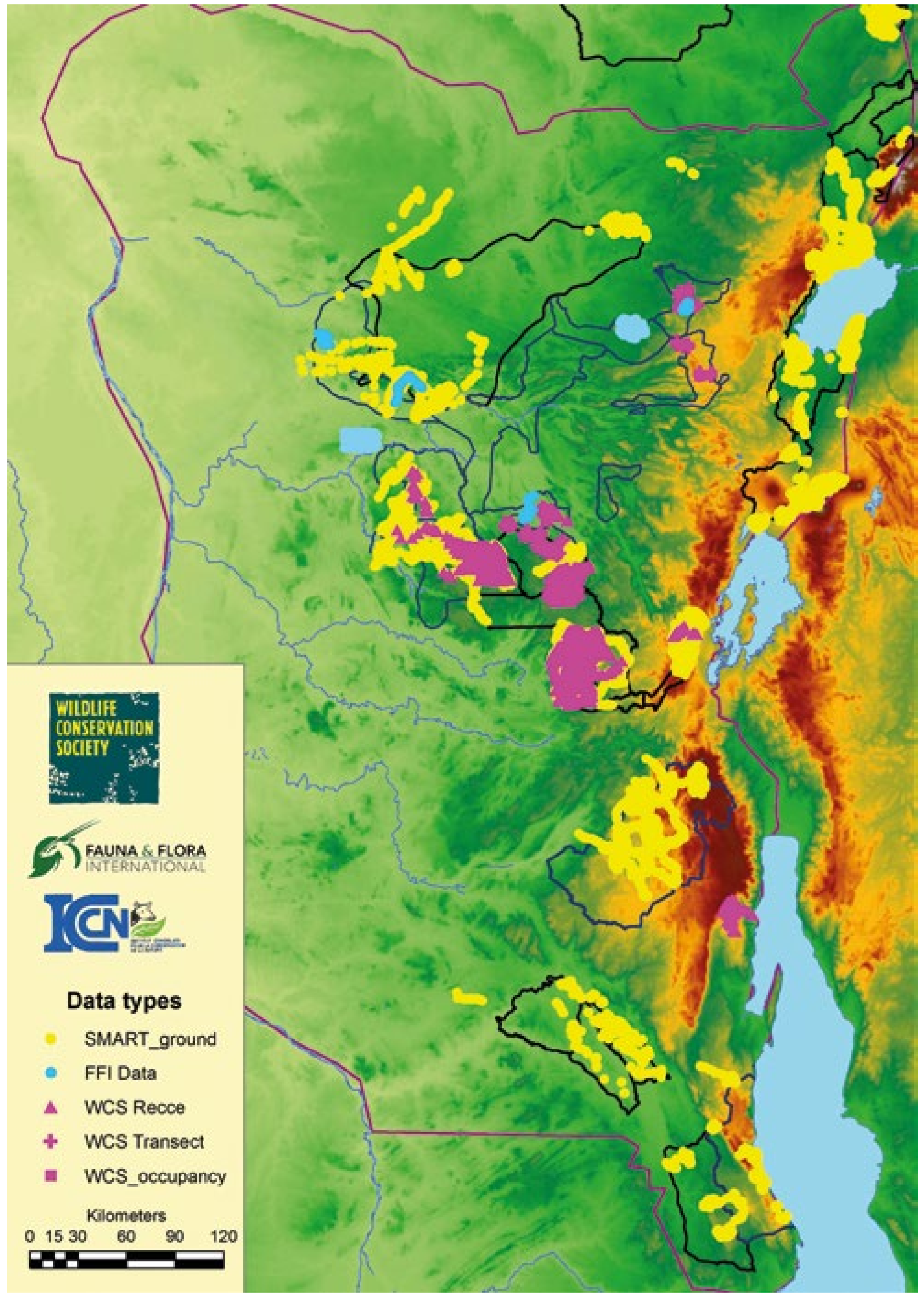


Figure 7. Areas surveyed with different methods used for the occupancy analysis. Data from SMART covered the largest number of cells. Background map is elevation from green (low) to brown (high)

We used covariables to predict from the sampled cells where we could calculate occupancy to estimate occupancy probabilities across the CAP Landscape. We used a combination of climate, topographic and human impact variables (Table 2). Initially we correlated these variables and removed those that had a Pearson correlation coefficient greater than 0.7. The final variables selected are given in Table 2 together with the data sources. Covariables were standardised by subtracting values from the mean and dividing by the standard deviation.

We ran the analyses using the hSDM Zero Inflated Binomial (ZIB) model which assumes no difference in detectability between replicates. In our case, we were sampling 1-km replicate lines around the same time in each cell so it was unlikely that there would be a major difference in detectability. The hSDM.ZIB() function uses a mixture model that combines a Binomial process for observability and a Bernoulli process for habitat suitability. Effectively it fitted a logistic curve to the covariable layers to predict occupancy across the landscape. We ran the model with and without a spatial correlation analysis. The spatial correlation analysis incorporated an intrinsic Conditional Autoregressive model (iCAR) which assesses the spatial configuration of the eight nearest neighbouring cells to each cell to measure the spatial autocorrelation. We ran the hSDM.ZIB and hSDM.ZIB.iCAR models in the following manner:

1. Run an hSDM.ZIB model with climate and topographical covariables
2. Select the significant variables from 1 and rerun hSDM.ZIB
3. Keep the significant variables from 2 and run hSDM.ZIB with human impact covariables also
4. Run hSDM.ZIB with variables from 2 and significant human impact covariables
5. Run hSDM.ZIB.iCAR with significant climate/topographical and human impact covariables

This allowed us to assess the importance of the climate, topographic and human impact variables on ape occupancy across the CAP Landscape. Significance was determined where the coefficient linked to the covariable did not overlap zero in the posterior distribution.

COMPARISON OF TREND ESTIMATES OF APE NESTS AND APE POPULATIONS

We wanted to estimate how Grauer's gorilla and chimpanzee numbers had changed from

Table 2. Covariables used for the analysis of ape occupancy across the landscape

Covariable Name	Measures	Source
Climate variables		
Bio2	Mean diurnal temperature range	WorldClim interpolated climate surfaces http://www.worldclim.org/
Bio12	Mean annual precipitation	
Bio17	Precipitation of driest quarter	
Topographic and forest variables		
dem	Elevation above sea level	SRTM data at University of Maryland http://glcf.umd.edu/data/srtm/
rugged	Ruggedness of topography	Available at http://diegopuga.org/data/rugged/#grid
slope	Slope – calculated from DEM layer	SRTM data at University of Maryland http://glcf.umd.edu/data/srtm/
stslopdis	Distance to steep slopes	Calculated by Lilian Pintea at Jane Goodall Institute from SRTM data
Treecov	Percentage tree cover	Calculated by Lilian Pintea at Jane Goodall Institute from Hansen et al. (2103)
Human impact variables		
disforlos	Distance to forest that has been recently lost	Calculated by Lilian Pintea at Jane Goodall Institute from Hansen et al. (2103)
minedist	Distance to artisanal mines	Data from International Peace Information Service and mine location data from SMART
rivdis	Distance to rivers	Calculated from data from UNOCHA in eastern DRC
roaddis	Distance to roads	
villdis	Distance to villages	

Communities in Usala carrying out a transect. *Credit S. Nixon*

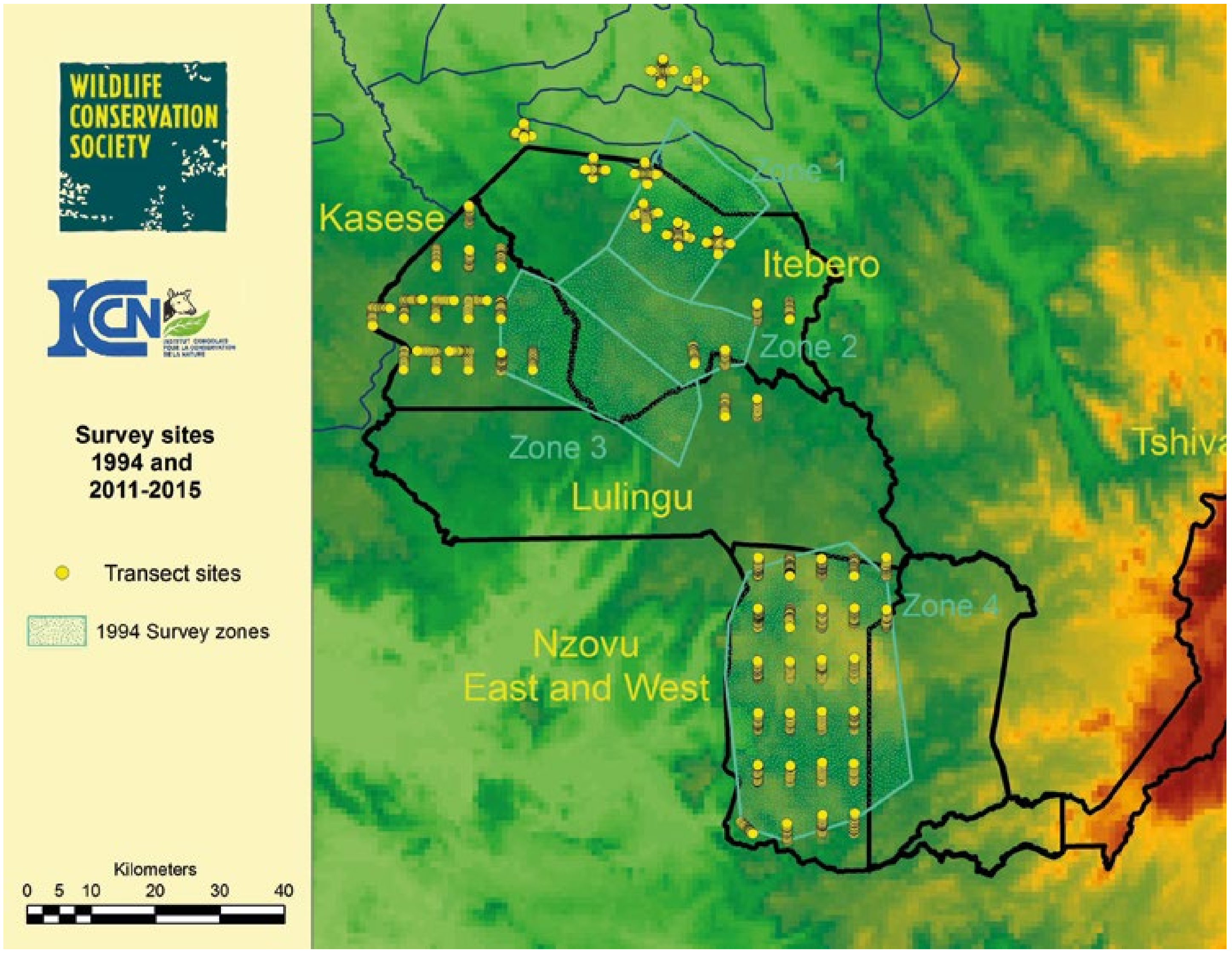


Figure 8. Map of Kahuzi-Biega National Park showing the four zones surveyed in 1994 with the location of transects (yellow circles for observations) from WCS surveys

previous surveys in this region and compile historical encounter rate and density data where we could obtain it. In particular, we wished to compare the 1994-95 density estimates for KBNP (Hall *et al.* 1998b) with more recent surveys in the same sectors of the park, because KBNP has been identified as a stronghold for this subspecies. There have been several predictions of major declines in Grauer's gorillas (Mehlman *et al.* 2008; Maldonado *et al.* 2012; Nixon *et al.* 2012), but few quantitative data to justify these claims. To facilitate comparison between the datasets, JSH and EAW re-transcribed data from the 1994 KBNP survey notebooks and datasheets and we re-analysed them using current approaches and DISTANCE 6 software (Thomas et al. 2010).

Re-analysis of 1994 transect survey data

The 1994 KBNP survey data consisted of perpendicular distance data to nests, noting which nests had been observed from the transect, and which were observed after the team left the transect to measure perpendicular distances and record the nest group size. In our re-analysis, we replicated the published analysis (Hall *et al.* 1998b) in which the authors calculated nest group density and multiplied this by nest group size to get an estimate of nest density. This was then converted to the number of weaned individuals by assuming a nest production rate each day of one nest per nest-building individual and dividing the nest density by a nest decay rate of 106 days obtained at Lopé in Gabon (Hall *et al.* 1998b; Tutin *et al.* 1995).

$$\text{Ape density} = \frac{\text{Average group size x Nest group density}}{\text{1 nest group per day x 106 days}}$$

WCS transect surveys 2011–2015

WCS has been aiming to repeat the surveys made in 1994 in the lowland sector of KBNP for several years, but insecurity in this area has made this difficult to achieve. Four zones were surveyed in 1994 (Fig. 9), three in the northern Itebero and Lulingu Sectors (Zones 1–3) and one in the southern Nzovu Sector of the park (Zone 4). WCS was able to undertake an intensive survey of the Nzovu Sector in 2013 and 2014 with 26 transects completed of 3 km length. Teams were also able to access the Itebero-Lulingu sectors briefly at two sites in 2011 and 2013 and to visit the western Kasese region in 2013 and 2015 (Fig. 8).

Comparison of encounter rates

To compare trends obtained from Kahuzi-Biega with other sites we also compiled encounter rates of ape nests per kilometre of transect or reconnaissance walk (recce) from prior surveys made at all sites where Grauer's gorillas and chimpanzees have been surveyed, either from unpublished data or published literature.

RESULTS

ICCN ranger measuring gorilla dung in a fresh night nest. *Credit A. Plumptre/WCS*

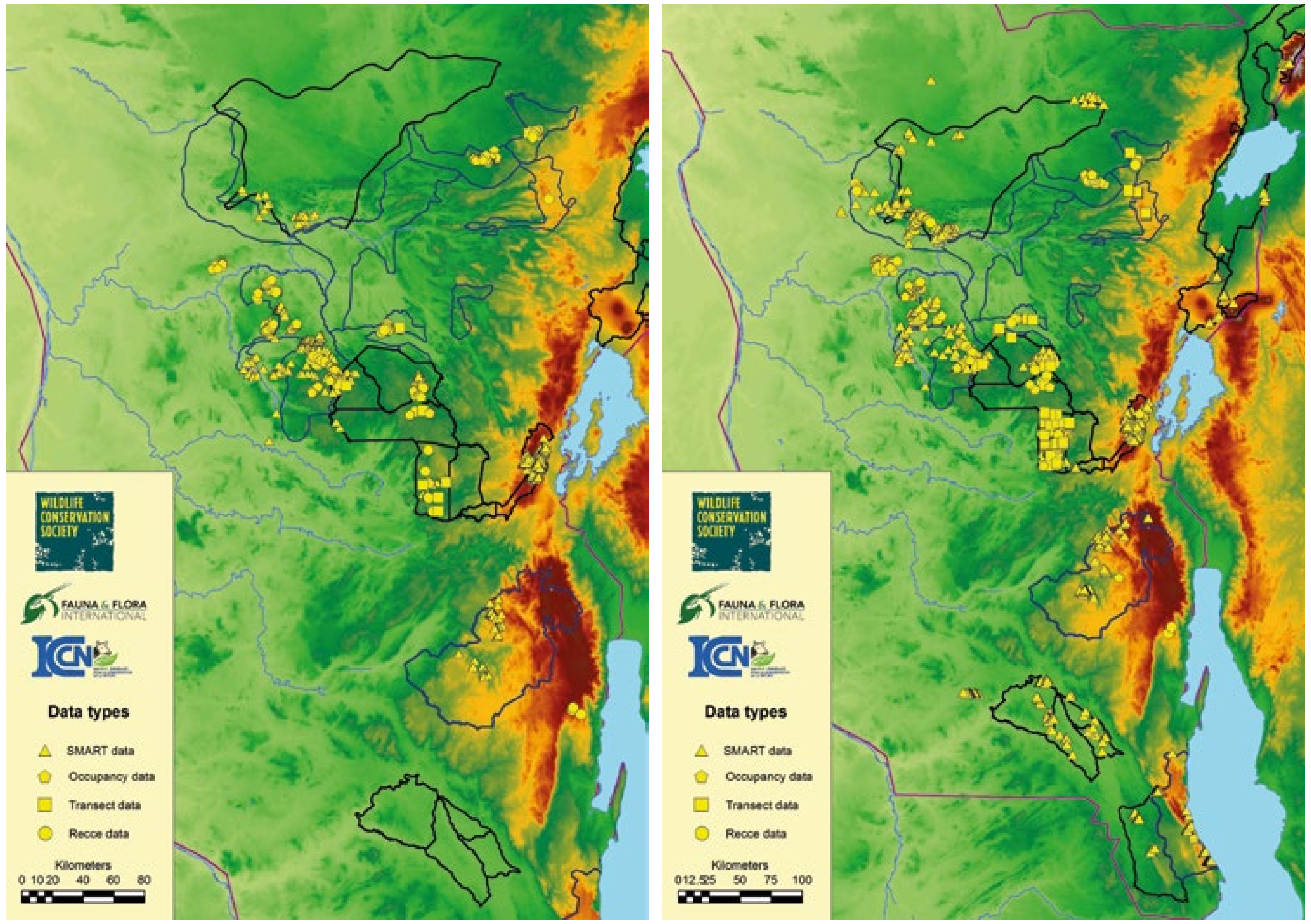


Figure 9. Locations of observations of signs of Grauer's gorillas (left) and chimpanzees (right) from: SMART data collected by ICCN and local communities, occupancy surveys by WCS and FFI, transect data by WCS and FFI, and recce data by WCS.

OCCUPANCY ANALYSIS

Gorilla and chimpanzee signs were recorded across a large part of the area surveyed between 2011 and 2015 (Fig. 9). These maps show the most extensive assessment of gorilla and chimpanzee distribution ever made in this region and that the general distribution of gorillas is similar to surveys in 1959/1960 and 1994 (Fig. 4).

However, some populations may have gone extinct or become so reduced in numbers to go undetected in our recent surveys. Notably gorillas documented in 2005 (Nixon *et al*. 2005) west of Maiko National park near Mundo and Okungu could not be located during FFI surveys in 2010 (Nixon 2010) and in 2013/2014 (this study). The northern Lowa population described by Hall et al. (1994) has disappeared from the vicinity of Penedjali village, however we documented three small families approximately 20 km north of Penedjali. Similarly a small population documented in 2005 (Nixon *et al*. 2005) on the north bank of the Lowa at the confluence of the Oso and Lowa rivers could not be found during our surveys in 2010 and 2014. However, more intensive, non-systematic searches in this area by FFI and communities located two small families in this region (5–7 individuals) in 2015.

The data from the SMART patrols, recces, transects and occupancy surveys were used in the spatial occupancy analysis for both species. The results are presented here for the significant covariables in step 2 and 4 and 5 (see page 18) in the analysis of occupancy (Table 3). For both gorillas and chimpanzees only one human impact variable was significant; distance to recent forest loss and distance to roads respectively. Higher occupancy probabilities of chimpanzees occurred closer to roads and as such they are probably not predicting ape occupancy but happen to be in areas where occupancy was high. This variable was therefore not incorporated in the final models. The details of the occupancy results are given in Appendix 1.

Arboreal gorilla nest site. *Credit S. Nixon*

Table 3. Covariables significant in model 2 (climate and physical variables) and model 3 (human impact variables) for each species of great ape

Model type	Grauer's gorilla	Chimpanzee
Climate and physical variables	dem (+ve), disforlos (+ve), treecov (+ve)	bio2 (-ve), dem (-ve), treecov (+ve), slope (+ve)
Human impact variables	Minedist (-ve)	Roaddis (-ve)
Climate and physical variables – spatial component included	dem (+ve), disforlos (+ve), treecov (+ve)	bio2 (-ve), dem (-ve), treecov (+ve), slope (+ve)
Detection probability with iCAR model	0.111	0.092
Mean Occupancy probability with iCAR model	0.073	0.431

Incorporating spatial correlation significantly changed the results obtained and produced occupancy probability maps that were more realistic when compared with findings of the surveys and addressed the over-prediction of occupancy probabilities where gorillas have never been observed (Fig. 10).

Grauer's gorillas

The occupancy of Grauer's gorilla was mapped (Fig. 11) using the five steps as described on page 22 of the methods. It identified three significant covariables that were used in the final hSDM.ZIB.iCAR model: elevation, tree cover and distance to areas of recent forest loss. Distance to mines was also significant but as the coefficient was negative (ie more gorillas the nearer to mines they were found) this was interpreted as a result that mines have tended to be placed in remote areas where gorillas also occur across this landscape and that this covariable did not act as a predictor variable. To give an estimate of the model performance, we computed the percentage of deviance explained by each model comparing it with a NULL model and FULL model. The NULL model is a model with only a mean for the probability of presence and no explicative variable. The FULL (or

Discharged shotgun shells collected on surveys west of Walikale. *Credit C. Kaghoma/FFI*

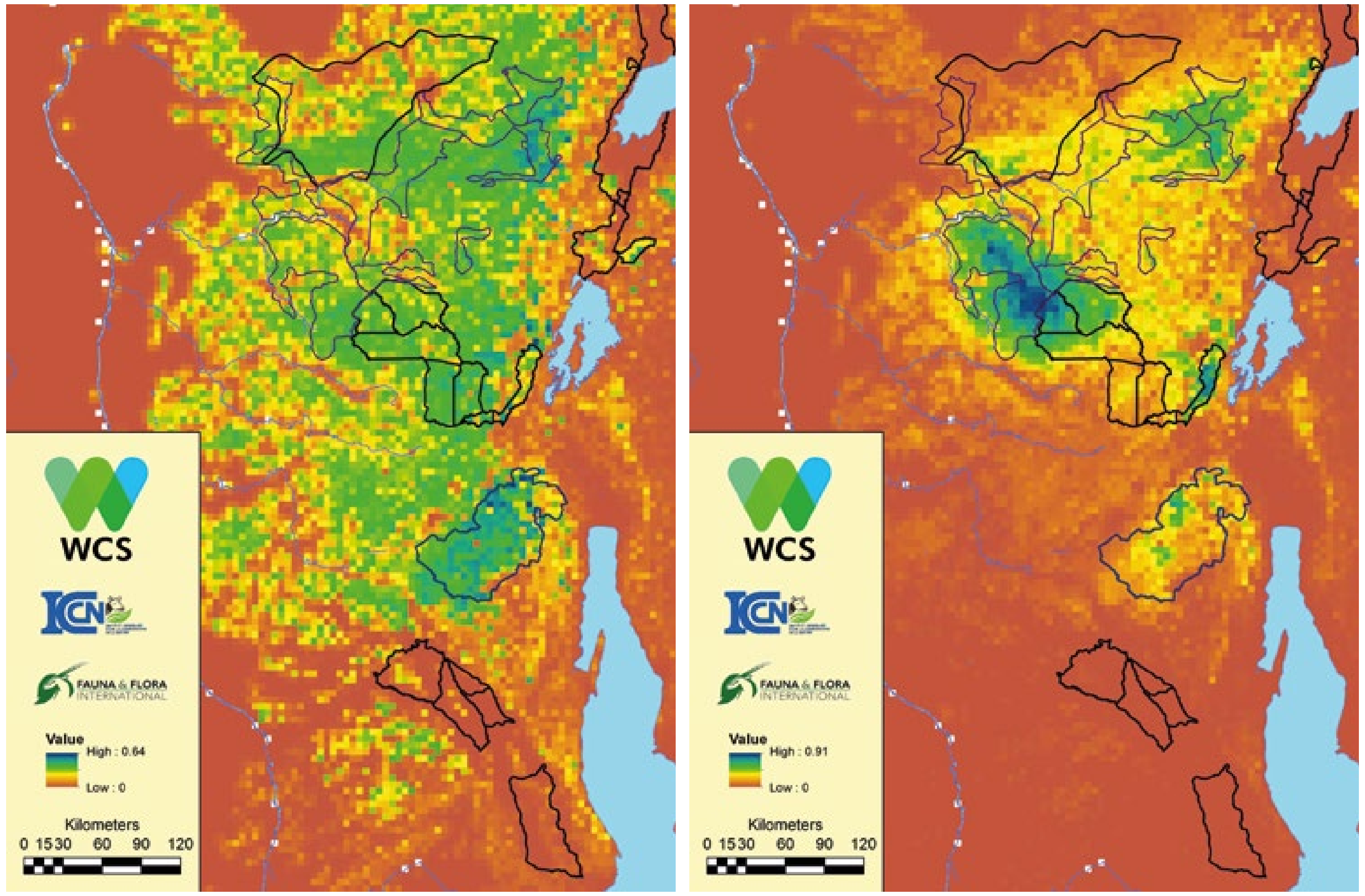


Figure 10. Occupancy map for Grauer's gorillas using statistically significant climate and physical covariables (left) and with a spatial Conditional Autoregressive Model (iCAR) and the same covariables (right).

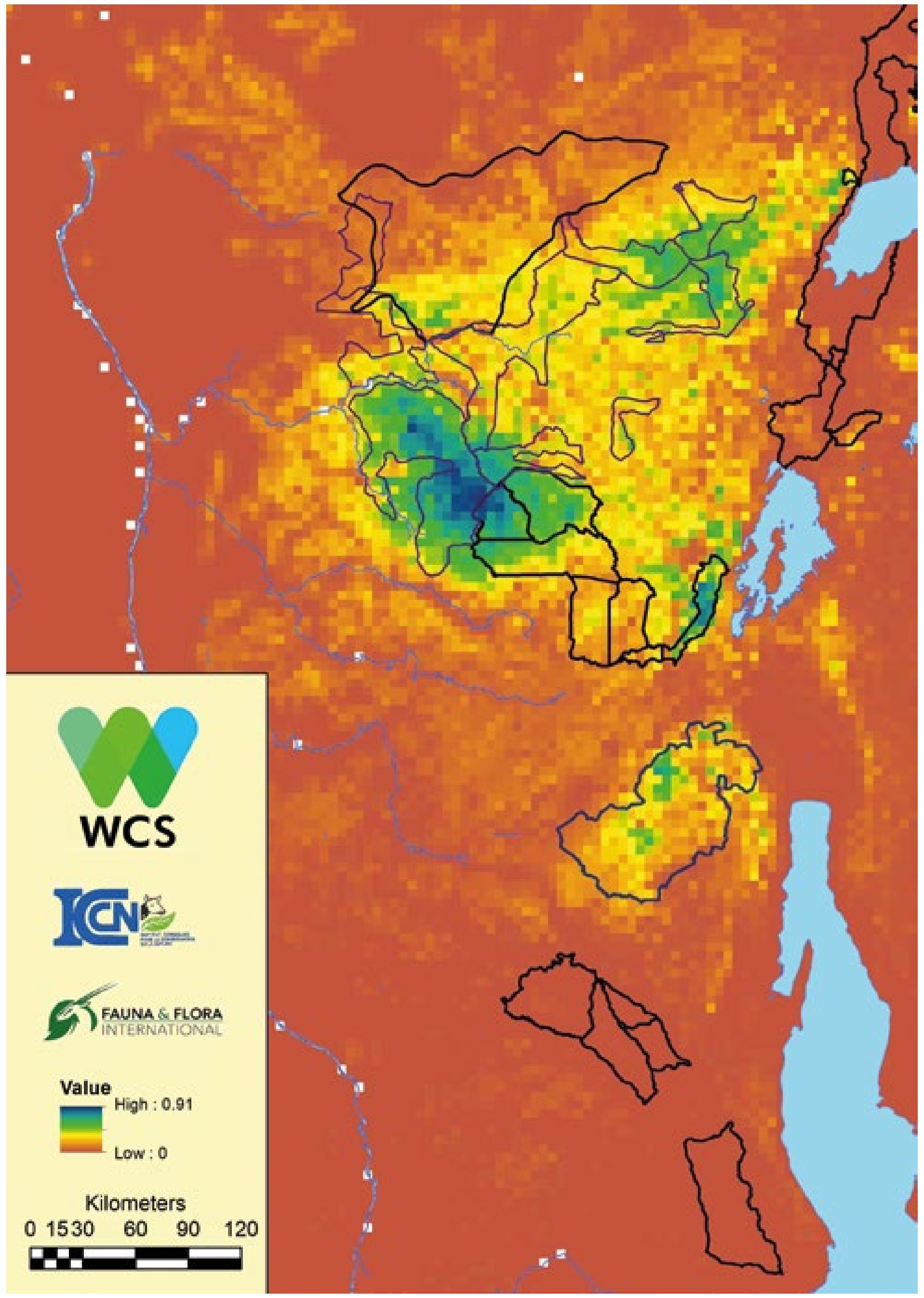


Figure 11. Occupancy probability map for Grauer's gorilla using the significant covariables and spatial effects

Fresh gorilla dung, Usala. *Credit C. Kaghoma*

Artisanal gold miners, west of Maiko National Park. *Credit S. Nixon*

saturated) model is a model with as many parameters as observations for the suitability process. The three covariables explained 17% of the Deviance scores. Including the spatial random effects, we were able to explain 56% of the deviance. The probability of a gorilla being found in a 5x5 km cell was 0.073 and the probability of detecting it was 0.111 (Table 3).

Chimpanzees

Chimpanzees were more widespread and had a higher occupancy probability across the landscape (Fig. 12). Four significant covariables that were used in the final hSDM.ZIB.iCAR model were identified: mean diurnal temperature range, elevation, tree cover and slope. Only distance to roads was significant for the human impact variables but as the coefficient was negative (i.e. more chimpanzees the nearer to roads they were found) this was interpreted as a result that roads have tended to be placed across remote areas where chimpanzees also occur across this landscape and do not act as a predictor variable. To give an estimate of the model performance, we again computed a NULL model and FULL model. The four covariables explained 16% of the Deviance scores. Including the spatial random effects, we were able to explain 38% of the deviance. The probability of a chimpanzee being found in a 5x5 km cell was 0.431 and the probability of detecting it was 0.092 (Table 3).

Detection probability was very similar for Grauer's gorillas, but occupancy probability was six times greater for chimpanzees than for gorillas. This is likely due to two factors: firstly gorillas move around their home ranges in cohesive groups, whereas chimpanzees live

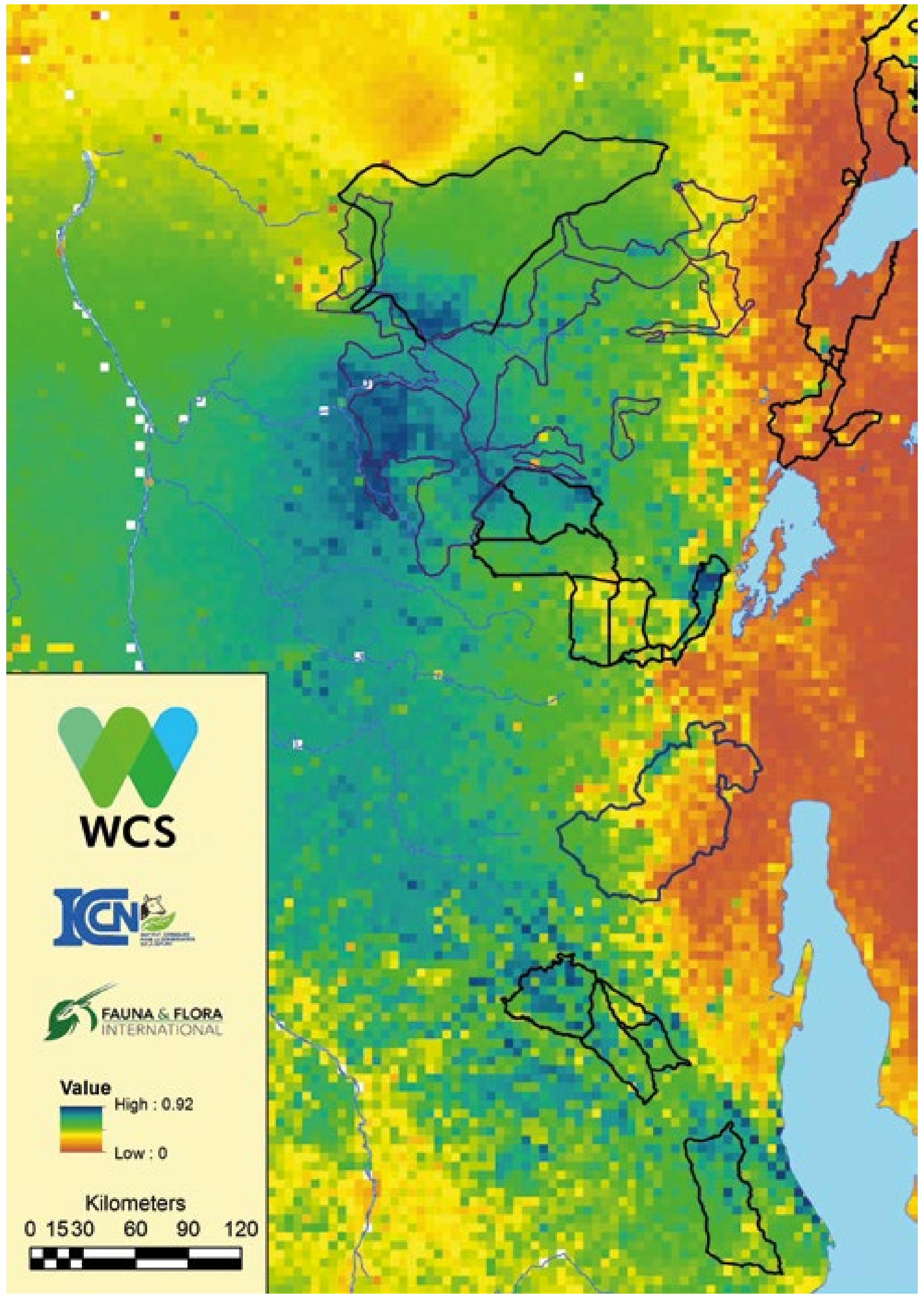


Figure 12. Occupancy probability map for chimpanzees using the significant covariables and spatial effects

Chimpanzee feeding sign (chewed bamboo wadges). *Credit S. Nixon*

in communities where individuals split up and come together in a "fission–fusion" society. Secondly, gorillas groups often leave a high density of localized sign as they move through their relatively small annual home ranges. Gorillas also have shorter day journey lengths than chimpanzees. These combined factors make gorillas easier to locate and kill where they occur. The cohesive social structure of gorillas (being protected by a single dominant adult male) also puts them at considerable hunting risk. Local hunters throughout the Maiko-Tayna region, report that it is easy to kill several gorillas at once. Chimpanzees on the other hand can disperse more quickly and are less likely to engage aggressively with their attacker than gorillas.

COMPARISON OF DENSITY ESTIMATES

Survey effort and detection curves

A total of 240.2 km of line transects were walked by WCS field staff between 2011–2015 in KBNP lowlands, north of Kahuzi and west of Itebero, the *Forêts pour le Développement Intégral* (Fodi), and in the Tayna and Kisimba Ikobo Community Reserves. Recce data exist for many more areas, but we elected to analyse transect data only to make comparisons with the 1994 density estimates. Only 27 nest groups of gorillas were sighted on the recent transects giving an encounter rate of 0.11 nest groups per km walked. This is really too few to reliably estimate nest density using perpendicular distance methods. We therefore combined the 2011–2015 data with the 1994 data and analysed both data sets using survey year as a covariable.

We could have assumed that the detection curve would have been the same in 1994 and 2011–2015, but given that observers were not the same, plus the vegetation structure could have changed during the 20-year gap between surveys, the data were analysed using the Multi-covariate distance sampling (MCDS) option in DISTANCE, using survey period as a covariable factor. This allows an analysis with different detection curves for the two time periods (Fig. 13). There was quite a difference in the perpendicular distance of sightings of gorilla nest groups (Fig. 13), but no obvious differences for chimpanzee nest groups, so in the case of chimpanzees we combined the two time periods to analyse the data with a single detection function (Fig. 14).

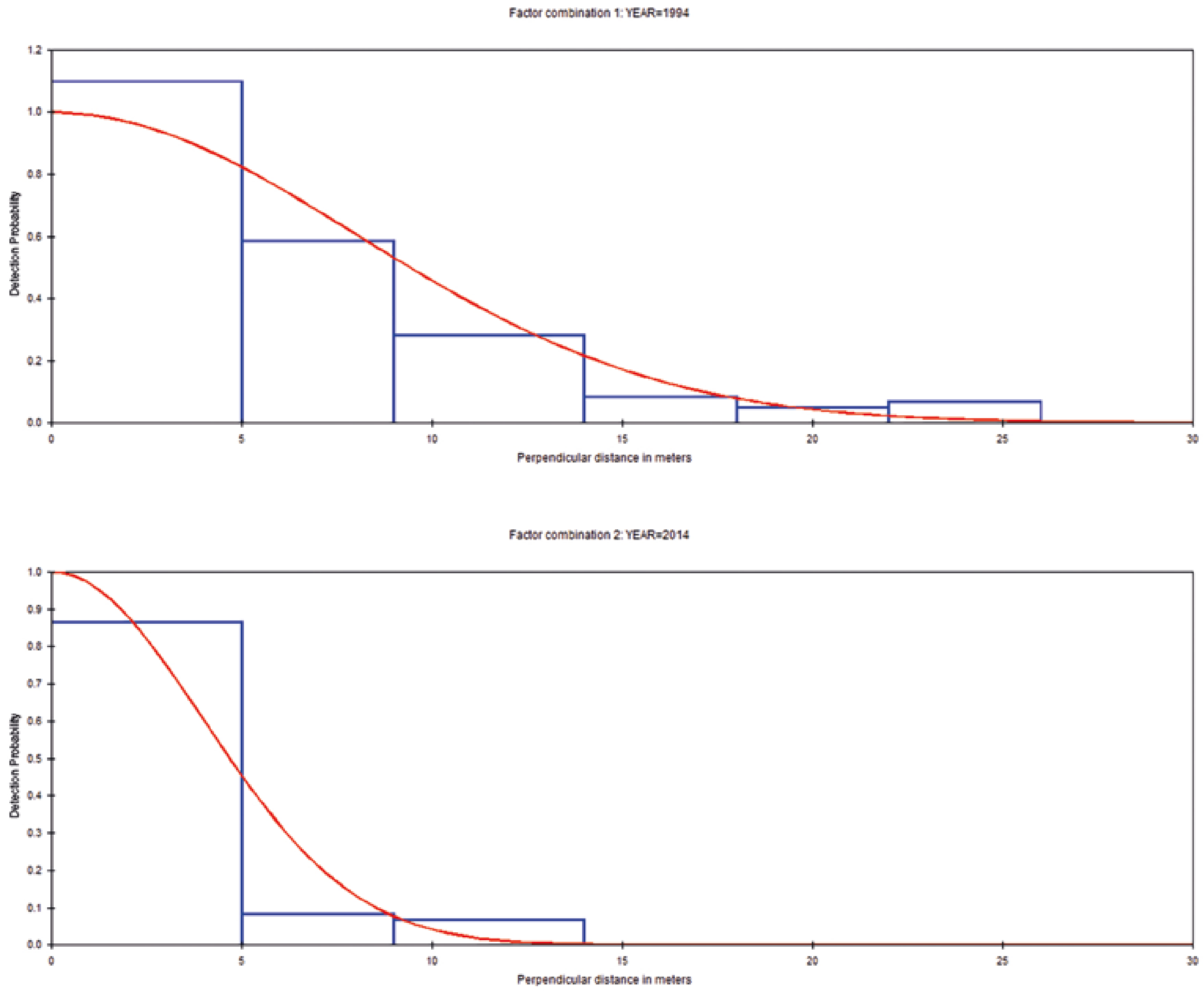


Figure 13. Detection curves, plotting the probability of detecting gorilla nest groups (Y-axis) with perpendicular distance from the transect (X-axis); 1994 data (top) and 2011–2015 data (bottom)

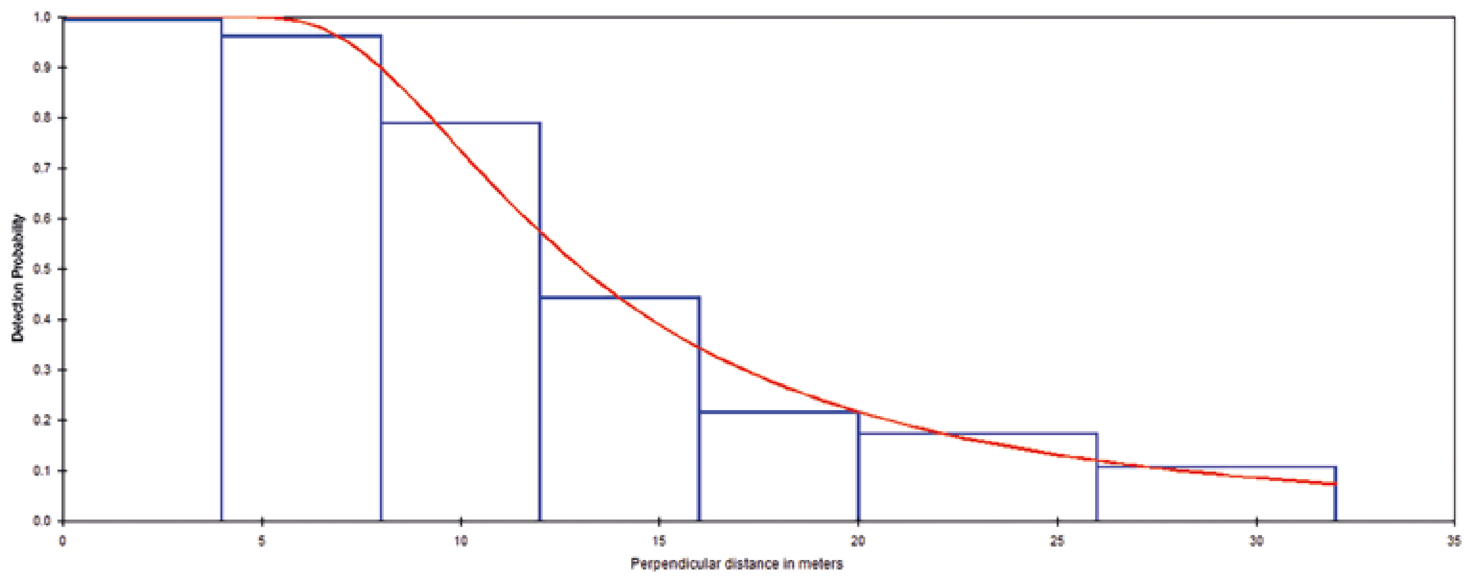


Figure 14. Detection curve, plotting the probability of detecting chimpanzee nest groups (Y-axis) with perpendicular distance from the transect (X-axis). Data were combined for both time periods, as the curves were very similar

GORILLA DENSITIES

Mother and infant Grauer's gorilla, Kahuzi-Biega National Park. *Credit A. Plumptre/WCS*

Gorilla nest group densities estimated for both 1994 and 2011–2015 are given in Table 4. We multiplied nest group density by an average group size of 6.4 nests per group (as in Hall *et al.* 1998b) for the 1994 data. As we had few fresh nests for the recent surveys, we compared average nest group size of all nest sites in the 1994 dataset with the nest group size in the 2011–2015 dataset. We found that the average group size was 4.0 for 1994 and 4.25 for 2011–2015 and so used the same group size as in 1994 of 6.4 nests per group of fresh nests. We multiplied this by the nest group density to obtain an estimate of gorilla density and then multiplied the gorilla density by the area of study to estimate the population size at each site. These results show an 87% decline in the gorilla population in the Itebero and Nzovu sectors of KBNP.

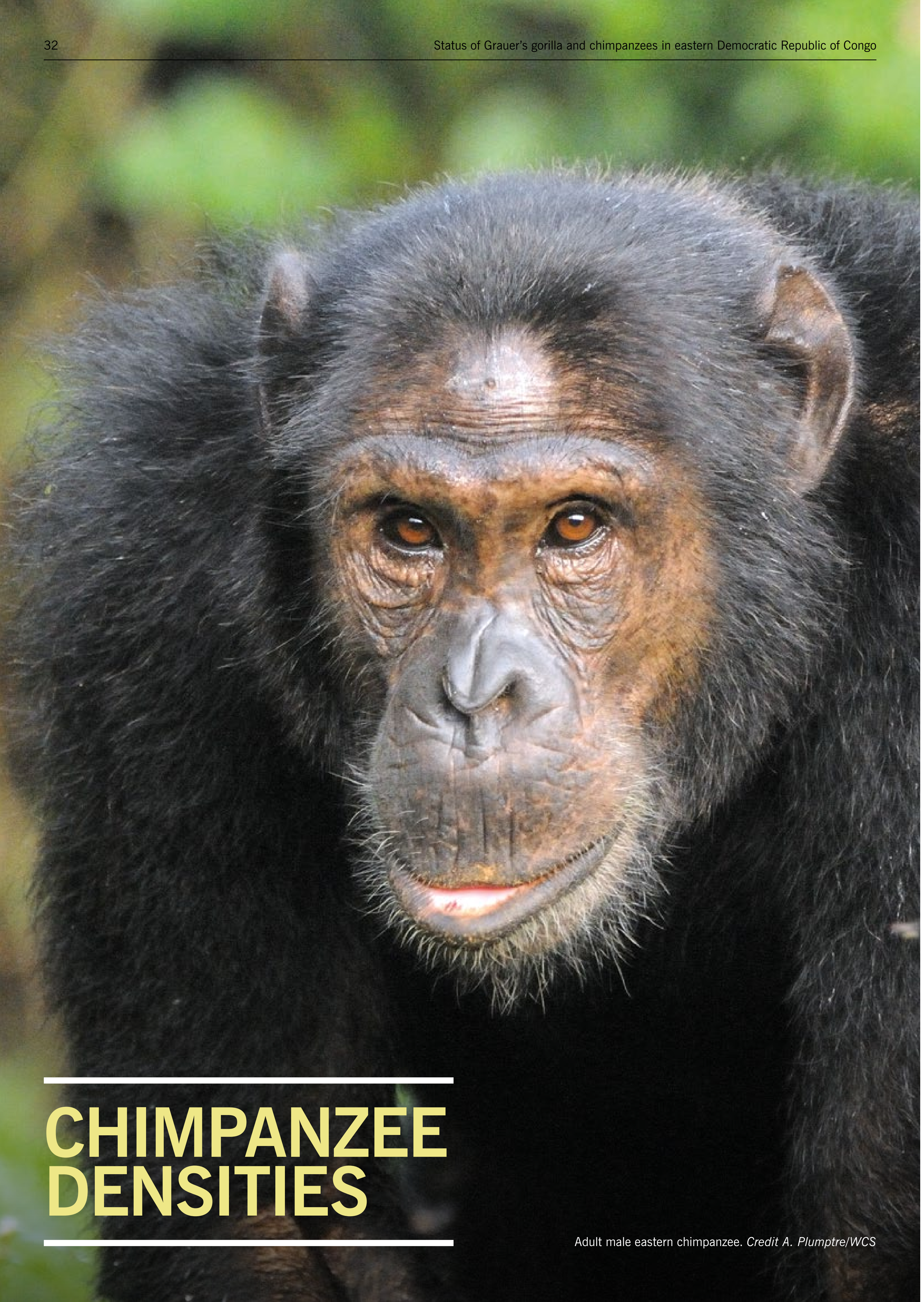
Adult male Grauer's gorilla, Kahuzi-Biega National Park. *Credit S. Nixon*

Table 4. Estimated density of gorilla nests, density of gorillas, and total number of weaned gorillas at various sites surveyed in 1994 (yellow) and 2011–2015.

Site	Year	Area km²	Nest group density	Gorilla density	Population estimate	95% confidence limits
Kahuzi-Itebero-Lulingu	1994	2,925	0.301	1.926	5,635	2,995–10,633
Kahuzi-Nzovu	1994	1,921	0.108	0.691	1,188	605–2,343
Kahuzi-Itebero-Lulingu	2011–2015	2,925	0.035	0.224	655	206-2,134
Kahuzi-Nzovu	2011–2015	1,921	0.021	0.134	258	86–811
Kahuzi-Kasese	2011–2015	716	0.040	0.256	183	60–536
Fodi	2011–2015	200	0.019	0.122	24	4–147
Tayna-Kisimba-Ikobo	2011–2015	1,869	0.067	0.289	541	121–2,414

Table 5. Estimated density of chimpanzee nests, density of chimpanzees, and total number of weaned chimpanzee at various sites surveyed in 1994 (yellow) and 2011–2015.

Site	Year	Area km²	Nest group density	Chimpanzee density	Population estimate	95% confidence limits
Kahuzi-Itebero-Lulingu	1994	2,925	0.178	0.348	912	505–2,065
Kahuzi-Nzovu	1994	1,921	0.318	0.642	1,101	613–2,479
Kahuzi-Itebero-Lulingu	2011–2015	2,925	0.071	0.263	768	292–2,025
Kahuzi-Nzovu	2011–2015	1,921	0.180	0.512	982	451–2,137
Kahuzi-Kasese	2011–2015	716	0.033	0.047	34	13–88
Fodi	2011–2015	200	0.255	0.983	197	89–433
Mt Hoyo	2014	317	0.168	0.383	142	44–453
Tayna-Kisimba-Ikobo	2011–2015	1,869	0.228	0.684	1,277	409–3,990



CHIMPANZEE DENSITIES

Adult male eastern chimpanzee. *Credit A. Plumptre/WCS*

A similar analysis was made for chimpanzee densities at sites where we had transect data (Table 5). Chimpanzee nest group size differed between 1994 and 2011–2015, averaging 2.0 in 1994 for both fresh nests and all nests combined, and 4.6 for KBNP lowland sector in 2011–2015. We therefore used the group sizes recorded in the field to calculate chimpanzee densities in the recent surveys. These results show a 22% decline in chimpanzee numbers between 1994 and 2011–2015 in the lowlands of KBNP.

It is clear that chimpanzees have fared better in the lowland Itebero-Lulingu and Nzovu sectors of KBNP, declining by about 22% in density compared with an 87% loss of gorillas. This is likely due to the social system of chimpanzees, which do not move in cohesive groups, but have a fission-fusion social system and usually occur in small parties or alone. This makes it harder for poachers to track and find them, so they have not declined as rapidly.

COMPARISON OF ENCOUNTER RATES FOR DIFFERENT SITES

Encounter rate data for gorilla and chimpanzee nests obtained from several sites (Table 6) show historical trends in the populations over time. Nearly all sites show a decline in encounter rates of gorillas (Fig. 16) and of chimpanzees (Fig. 17) indicating that the decline in densities found in KBNP is mirrored in the trends in encounter rates of nests at all sites where gorillas occur.

Table 6. Encounter rates (E-rate) of nests of gorillas and chimpanzees per kilometre walked

Site	Year	Recce or transect	Distance walked (km)	Gorilla nest E-rate/km	Chimpanzee nest E-rate/km	Source
Itombwe Reserve						
Itombwe	1996	Recce mainly	541.2	0.61	1.79	Omari et al. 1999
Itombwe Kitopo-Makenda	2006	Transect	88.74	0.82	1.50	WCS
Itombwe Ulindi	2008	Transect	51.63	0.04	0.95	WCS
Itombwe West Mwana	2008	Transect	37.63	0	0.80	WCS
Itombwe – SMART	2013–2014	Recce	1,130.52	0.02	0.02	ICCN/WCS
North Balala Forest						
Balala	1996	Recce	53.4	0.17	N/A	Omari et al. 1999
Balala	2013	Recce		0.00	0.00	WCS
Kahuzi-Biega National Park						
Kahuzi-Biega Tshivanga	2000	Recce	307.35	0.89	2.61	WCS
Kahuzi-Biega Tshivanga – SMART	2014–2015	Recce	4,273.71	1.31	0.09	ICCN/WCS
Kahuzi-Biega Itebero Zone 1	1994	Transect	76.41	2.21	2.51	Hall et al. 1998
Kahuzi-Biega Itebero Zone 2	1994	Transect	69.02	3.82	0.68	Hall et al. 1998
Kahuzi-Biega Itebero Zone 3	1994	Transect	74.60	1.14	0.26	Hall et al. 1998
Kahuzi-Biega Itebero Zone 1	2006	Recce	85.17	0.06	0.25	WCS/ICCN
Kahuzi-Biega Itebero Zone 1	2011	Transect	22.0	0.09	0.27	WCS/ICCN
Kahuzi-Biega Itebero Zone 1	2013	Transect	15.50	0.00	0.19	WCS/ICCN
Kahuzi-Biega Itebero – SMART	2014–2015	Recce	172.38	0.08	0.3	ICCN/WCS
Kahuzi-Biega Nzovu Zone 4	1994	Transect	100.00	1.21	2.11	Hall et al. 1998
Kahuzi-Biega Nzovu	2007	Recce	355.22	0.51	0.39	WCS/ICCN
Kahuzi-Biega Nzovu	2007	Transect	56.03	0.00	0.30	WCS/ICCN
Kahuzi-Biega Nzovu	2013	Transect	20.59	0.05	0.24	WCS/ICCN
Kahuzi-Biega Nzovu	2014	Transect	53.06	0.11	1.91	WCS/ICCN
Kahuzi-Biega Nzovu – SMART	2014–2015	Recce	745.84	0.04	0.05	ICCN/WCS

Site	Year	Recce or transect	Distance walked (km)	Gorilla nest E-rate/km	Chimpanzee nest E-rate/km	Source
Kahuzi-Biega Kasese	2010	Transect	158.55	0.01	0.17	WCS/ICCN
Kahuzi-Biega Kasese	2013	Transect	5.39	0.19	0.37	WCS/ICCN
Kahuzi-Biega Kasese	2015	Transect	59.46	0.18	0.16	WCS/ICCN
Kahuzi-Biega Kasese – SMART	2014–2015	Recce	332.73	0.10	0.06	ICCN/WCS
Reserve des gorilles de Punia/Kasese						
Kasese/RGPU Zone 1	1995	Transect	53.00	0.57		Hall et al. 1998
Kasese/RGPU Zone 2	1995	Transect	54.00	0.93		Hall et al. 1998
RGPU Zone1&2 – SMART	2014–2015	Recce	668.93	0.17	0.13	WCS/RGPU
Kasese/RGPU Zone 3	1995	Transect	54.00	0.72		Hall et al. 1998
Kasese/RGPU Zone 3	2010	Recce	141.17	0.00	0.00	WCS
RGPU Zone 3 – SMART	2014–2015	Recce	352.97	0.65	0.18	WCS/RGPU
Tayna Community Reserve						
Tayna	2004	Transect	68.90	2.35		Mehlman 2008
Tayna	2006	Recce/transect	89.00	4.48	2.52	S. Nixon/ DFGFI
Tayna	2013	Transect	11.96	0.25	0.42	WCS
Kisimba-Ikobo Community Reserve						
Kisimba-Ikobo	2013	Transect	11.06	0.00	1.08	WCS
Maiko National Park						
Maiko-South west	2005	Recce	170.00	0.42	0.42	S. Nixon/ DFGFI
Maiko - SMART	2014–2015	Recce	1,408.14	0.002	0.02	ICCN/WCS
Lubutu Community Reserve						
Lubutu	2010	Recce	230.30	0.00	0.22	S. Nixon/FFI
Usala Community Reserve						
Usala	2007	Recce	204.00	1.47	0.23	S. Nixon/DFGFI
Usala	2010–2013	Recce	212.76	1.37	0.26	S. Nixon/FFI
REGOMUKI Community Reserve						
REGOMUKI	2013	Recce	113.60	0.22	0.52	S. Nixon/FFI

Of the 11 sites with more than one estimate of gorilla encounter rate, only the Tshivanga sector (highland sector), the Kasese sector of KBNP, the very remote Usala region and the eastern part of RGPU show any signs of stable or increasing nest encounter rates (Fig. 15). The low recent value for Tayna Reserve may be an underestimate because field staff were not able to survey much of the reserve due to insecurity. The average rate of decline per year across the seven sites exhibiting a decline was 5.5% per year.

Chimpanzees are also declining at most sites (Fig. 16) with stable or increasing populations only at Usala and in the Reserve des Gorilles de Punia (Sector 3, which borders KBNP). The Nzovu sector of KBNP is also potentially stable but the trend line is pulled down by a low encounter rate in the mid 2000s. Recent data show a similar encounter rate to 1994. The average rate of decline for chimpanzee encounter rates across the six sites surveyed is 5.1% per year.

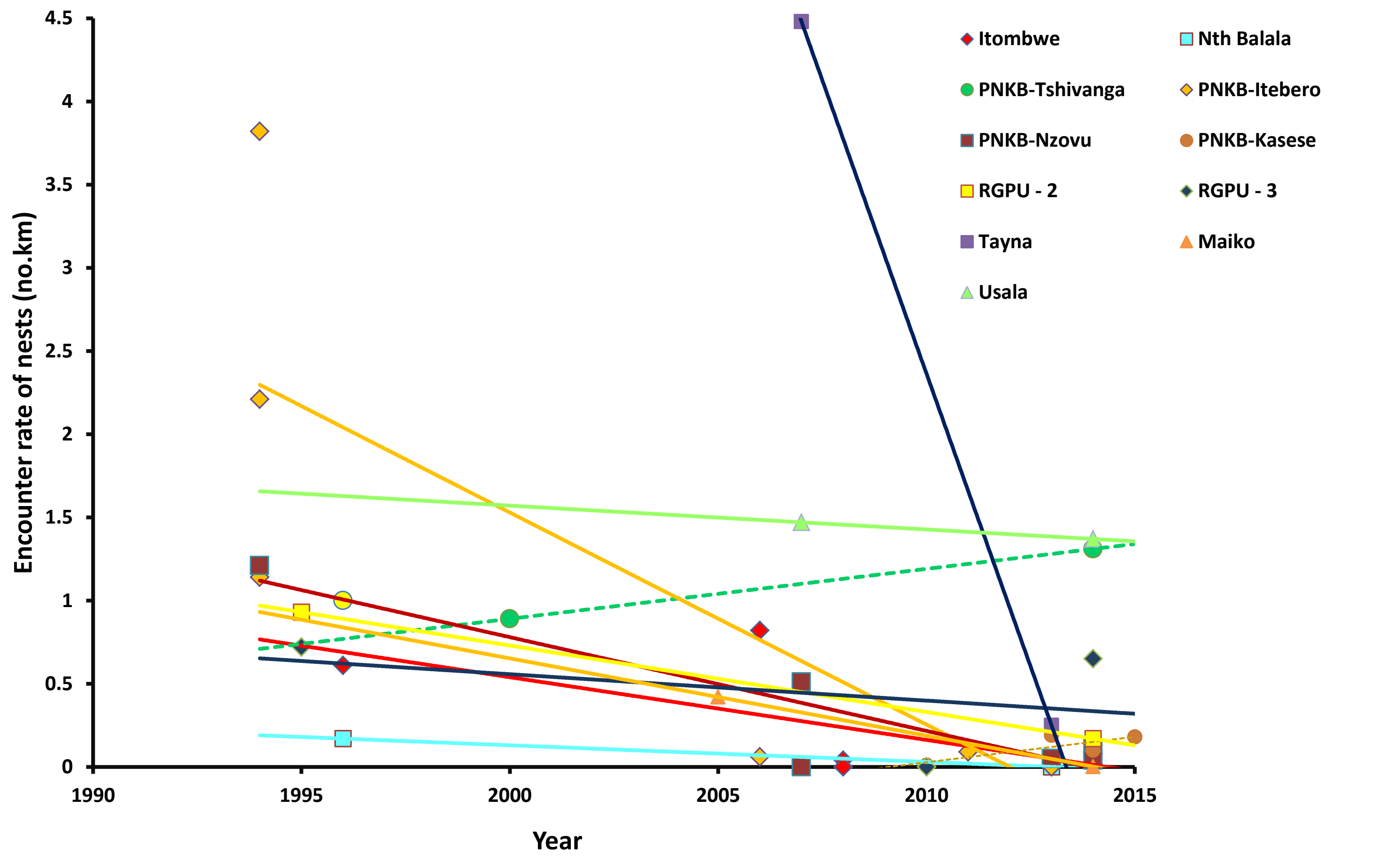


Figure 15. Encounter rates of gorilla nests per kilometre walked at various sites across the range of Grauer's gorillas. Regression lines for each site are plotted in the same colour as the points

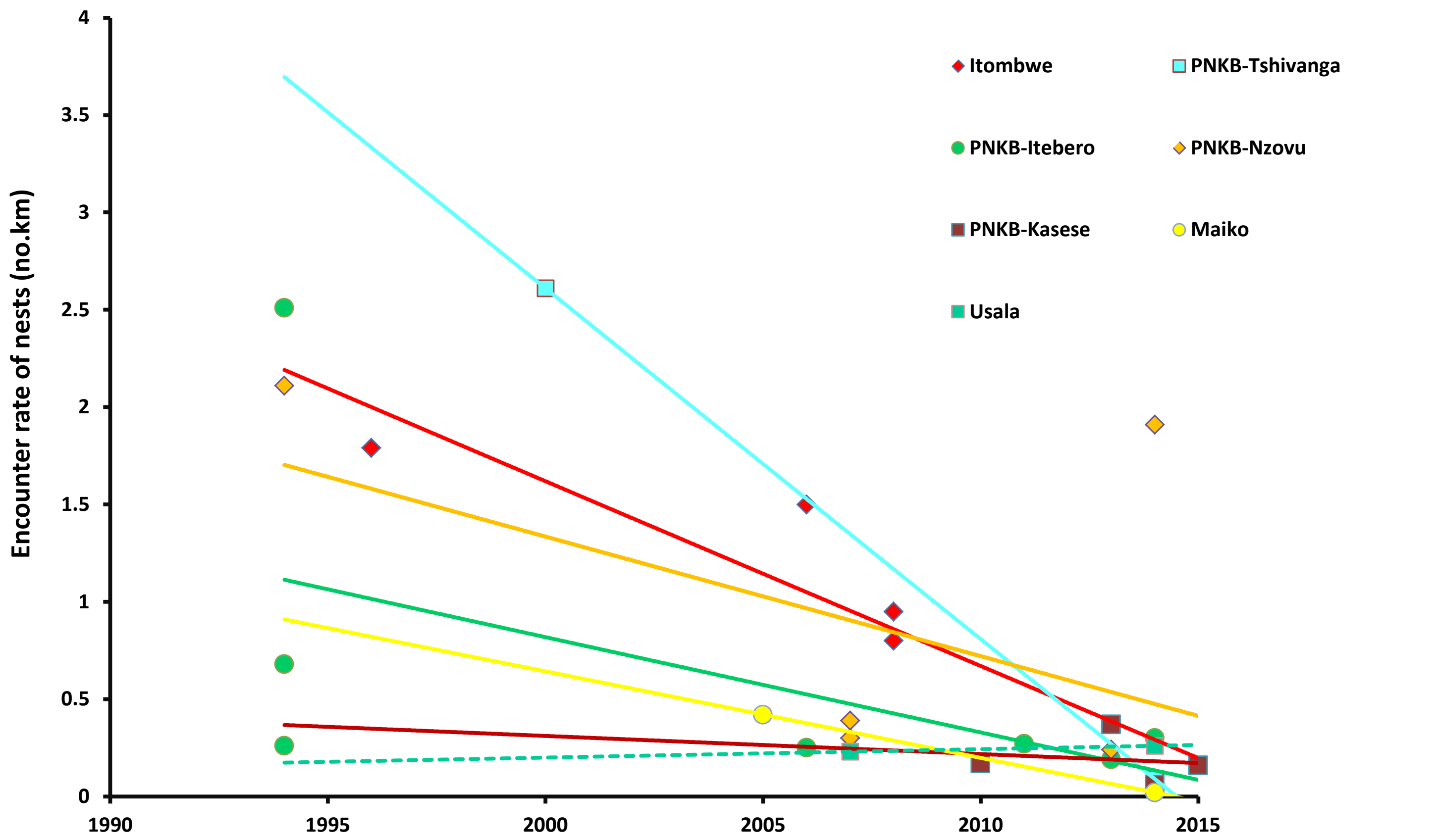


Figure 16. Encounter rates of chimpanzee nests per kilometre walked at various sites across the range of Grauer's gorillas. Regression lines for each site are plotted in same colour as points

Table 7. Estimated declines in gorilla and chimpanzee populations at various sites comparing encounter rates (%) from the oldest surveys to the most recent. Green = stable or increasing (–ve value) encounter rate; red = decreasing encounter rate

Site	Dates between comparisons	Gorilla percentage decline	Chimpanzee percentage decline
KBNP-Tshivanga	2000–2014	–47.19	96.55
KBNP-Kasese	2013–2015	5.26	5.88
Usala	2007–2014	6.88	–13
RGPU Zone 3	1995–2014	9.72	
RGPU Zone 2	1995–2014	81.72	
Tayna	2007–2013	89.36	
KBNP-Nzovu	1994–2014	90.9	9.5
KBNP-Itebero-Lulingu	1994–2014	96.23	80
Itombwe	1996–2014	96.72	98.88
Maiko	2005–2014	99.52	95.24
Balala	1996–2014	100	

Where declines have occurred, the average percentage loss of the population is 93.5% for gorillas and 92.7% for chimpanzees if calculated from encounter rates of nests (Table 7). Where we compared encounter rates, we compared estimates from transects and recces separately because they will be lower on recce walks, however encounter rates are not as robust a measure of population as density measurements because they are affected by issues of detectability of the nests. However, these steep declines will be indicative of real declines in the ape populations at these sites, as generally encounter rate correlates well with density for chimpanzees (Plumptre & Cox 2005).

CORRELATIONS OF ENCOUNTER RATES AND DENSITY

Using the data of encounter rates from transects and the density estimates obtained in the analyses presented here and from Hall *et al.* (1998b) we obtained significant correlations between the encounter rate of individual nests along transects and the density of the two apes (Fig. 17).

Using these equations and the values of encounter rate in table 7 we estimated a weighted average density for both chimpanzees and gorillas, weighting by the area of the study region surveyed, and estimated numbers of gorillas and chimpanzees in each site (Table 8).

Eastern chimpanzees feeding on figs. *Credit A. Houle*

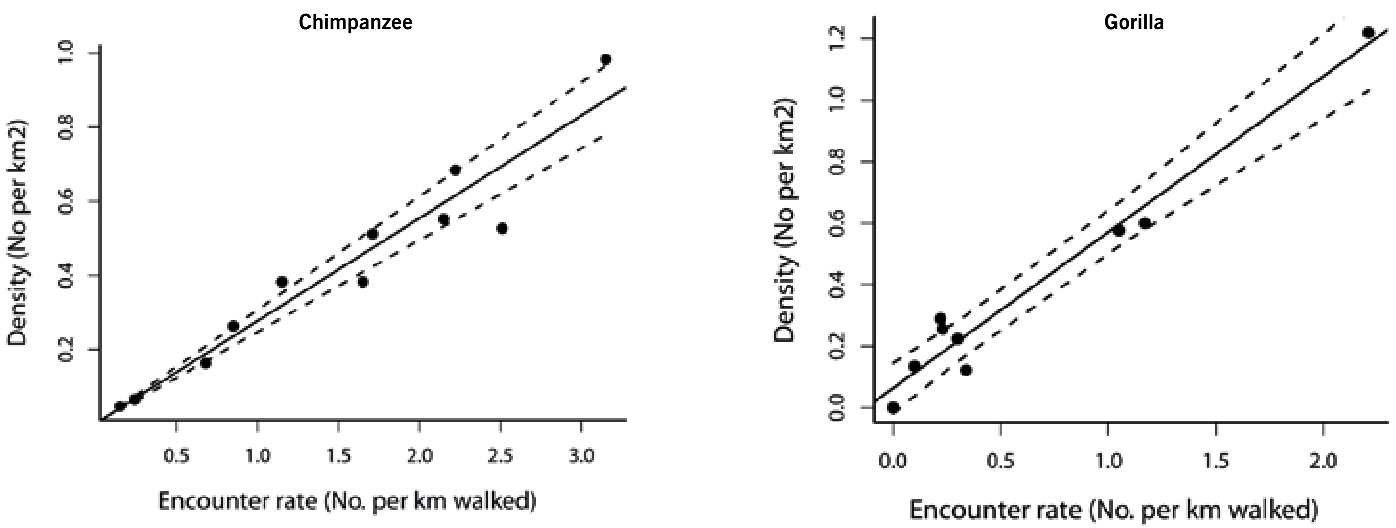


Figure 17. Correlation of encounter rate of nests (No. per km walked) and calculated densities (No. per km^2) for gorillas (top) and chimpanzees (bottom) with 5% and 95% confidence intervals (dashed lines)

Table 8. Estimated densities and numbers of gorillas and chimpanzees at various sites from encounter rate data (from transects, wherever possible)

		Chimpanzee		Gorilla	
Site	Area (km2)	Density	Number	Density	Number
Itombwe	5,600	0.222	1,241	0.014	79
Balala	400	0.000	0	0.000	0
Kahuzi-Biega Tshivanga	600	0.025	15	0.668	200
Kahuzi-Biega Itebero-Lulingu	2,925	0.236	689	0.205	599
Kahuzi-Biega Nzovu	1,921	0.474	910	0.077	148
Kahuzi-Biega Kasese	716	0.042	30	0.159	114
FODI	200	0.873	175	0.231	46
RGPU north	2,400	0.233	209	0.282	254
RGPU east	2,000	1.028	998	0.000	0
Tayna	900	0.036	86	0.118	284
Kisimba-Ikobo	971	0.050	100	0.422	845
Maiko	10,830	0.006	60	0.001	15
Lubutu	1,056	0.061	64	0.000	0
Usala	1,152	0.072	83	0.797	918
REGOMUKI	1,480	0.144	213	0.152	225
Mt Hoyo	317	0.457	145		
Total			**5,019**		**3,727**

PREDICTING APE NUMBERS FROM THE OCCUPANCY ANALYSIS

To transform the map of probabilities of presence from the occupancy analysis into a species distribution area we used a probability threshold. We computed the probability threshold maximizing the True Skill Statistic (TSS; Liu *at al.* 2011). This method identifies the best probability threshold by minimizing the prediction error for both presences and absences. The cells with an occupancy probability equal or higher than the threshold value can then be multiplied by the average density of the species calculated from the encounter rates and equations in the previous section.

Estimated gorilla numbers

We obtained a probability threshold of 0.35 (Fig. 18) and a maximal TSS of 0.86. This is a relatively high value of TSS indicating a good correspondence between our species distribution area and observed suitable and unsuitable sites. The area of 5x5 km cells with a value of 0.35 or greater was 20,100 km^2, which is the area predicted to have a presence of gorillas. The weighted mean density of gorillas across all sites was 0.129 per km^2 which, when multiplied by this area, gives an estimate of 2,585 Grauer's gorillas across their range. Computing lower and upper confidence limits around this number needs to take into account the error from the regression of encounter rate against density as well as the error in the hSDM.ZIB.iCAR model and the calculation of the TSS. Combining both sets of errors we obtained 1,802–4,528 as lower and upper 95% confidence limits.

Estimated chimpanzee numbers

We obtained a probability threshold of 0.5 (Fig. 19) and a maximal TSS of 0.67. This is a reasonable value of TSS indicating a reasonable correspondence between our

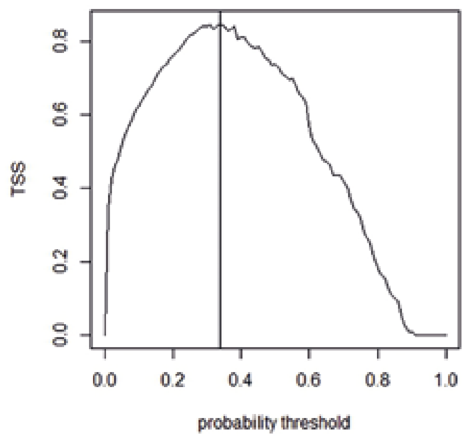


Figure 18. Plot of the True Skill Statistic against probability threshold identifying p=0.35 as the probability threshold for a maximum TSS of 0.86

species distribution area and observed suitable and unsuitable sites. The area of 5x5 km cells with a value of 0.50 or greater was 177,250 km^2, which is the area predicted to have a presence of chimpanzees. The weighted mean density of chimpanzees across all sites was

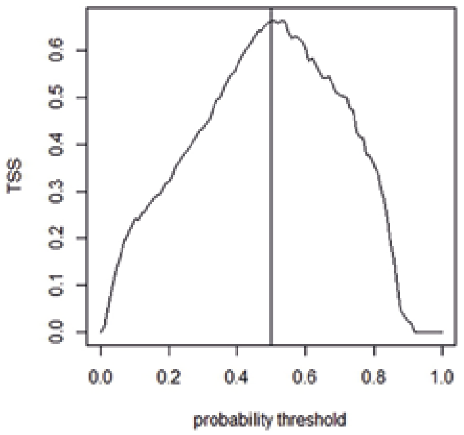


Figure 19. Plot of the True Skill Statistic against probability threshold identifying p=0.50 as the probability threshold for a maximum TSS of 0.67

0.213 per km^2, which when multiplied by this area gives an estimate of 37,740 chimpanzees across this landscape. Calculating the 95% confidence limits in the same way as for the gorillas, we obtained 14,019–67,196 as the lower and upper 95% confidence limits.

DISCUSSION

Population changes

These results show a major decline in the population of Grauer's gorilla across its range. In 1994, KBNP, together with the Kasese region to the west, contained 86% of the population (Hall *et al*. 1998a). The occupancy analysis and SMART, recce and transect surveys carried out in 2011–2015 indicate that these two areas are still very important for this species. Our estimate of the decline in Grauer's gorilla is 87% from the KBNP density estimates. Evidence from the encounter rate analyses also indicates an average of 94% decline in Grauer's gorilla at seven of the eleven sites for which we have data. When we compare the total population estimate of 17,000 (Hall *et al.* 1998b) with the 2,585 estimated in the occupancy model, this also shows an 84.7% decline in numbers. This devastation is due to the illegal hunting of the species for bushmeat, particularly around mining concessions that are often deep in the forests. Only the highland sector of KBNP has been reasonably well protected during this time and yet even here numbers were halved from 258 in 1993 to 130 in 2000 by bushmeat hunting, although this population recovered to 181 in 2010 (Table 9). Encounter rate data indicate continuing increases here.

The chimpanzee nest data also show major declines of the eastern chimpanzee in eastern DRC. Encounter rate data indicate an 81% decline on average where declines have occurred but that this varies greatly between regions. The density data from KBNP, which are more accurate because they incorporate detectability from the transect line, indicate much less of a decline with an estimated 22% decline for the lowland sector of the park. Encounter rate data for the same area indicate a 45% decline.

It is clear that where there is good protection such as in the highland area of KBNP that gorilla numbers can rebuild but that elsewhere where protection has been minimal it is only in the remote areas that gorillas are hanging on.

Table 9. Summary statistics for surveys of Grauer's gorillas in the highland sector of Kahuzi-Biega National Park, 1978–2010

Year	Gorilla groups	Gorilla numbers	Mean group size	Percentage infants	Solitary males
1978	14	223	15.6	17	5
1990	25	258	10.8	8.4	9
1996	25	245	9.8	12.7	2
2000	13	130	9.6	9.3	4
2004	15	168	10.7	15.9	2
2010	17	181	9.9	14.2	2

IUCN Red List status of Grauer's gorilla

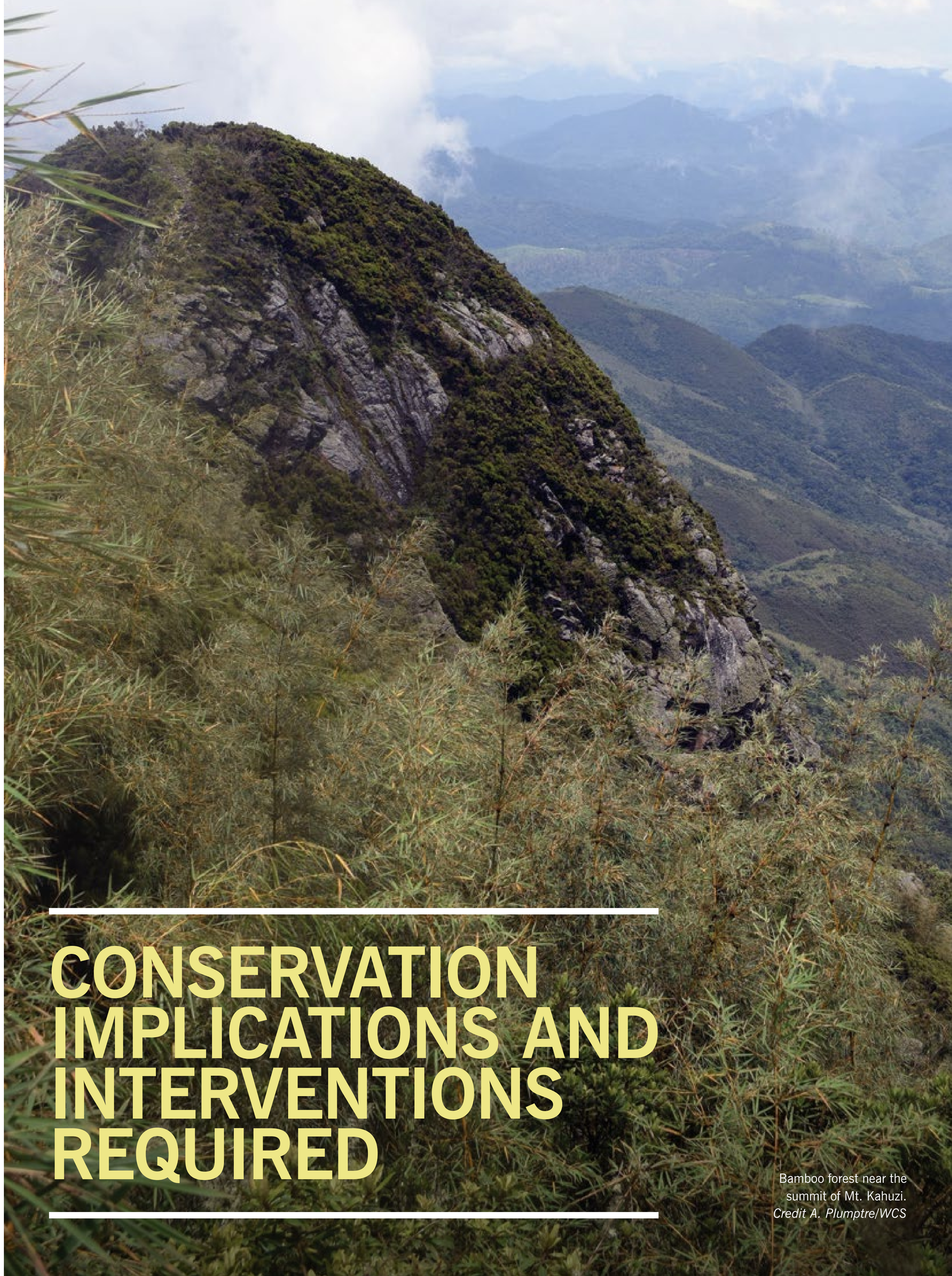
The data we present above justify listing Grauer's gorilla as Critically Endangered on the IUCN Red List of Threatened Species under the following criteria:

A2 (population reduction observed, estimated or inferred or suspected in the past where the causes of reduction may not have ceased OR may not be reversible) based on the following:

a. Direct observation
b. An index of abundance
c. Decline in area of occupancy (some populations have been extirpated)

A greater than 80% reduction of the population over three generations merits a Critically Endangered listing. We estimate an 87% reduction from density data, a 94% decline from encounter rate data, and an 84.7% reduction from the modelling data at several sites across its range. Surveys by FFI also failed to find gorillas in areas they used to frequent in Lubutu west of Maiko National Park. These changes have taken place over the period of about one generation (20 years) and we therefore recommend that the Red List status of this subspecies of eastern gorilla be raised to Critically Endangered. We estimate from the occupancy analysis that there are only about 2,585 (1,802–4,528) Grauer's gorillas remaining in the wild.

Adult male Grauer's gorilla, Kahuzi-Biega National Park. *Credit S. Nixon*



CONSERVATION IMPLICATIONS AND INTERVENTIONS REQUIRED

Bamboo forest near the summit of Mt. Kahuzi. *Credit A. Plumptre/WCS*

ICCN rangers carrying out an anti-poaching patrol, Kahuzi-Biega National Park. *Credit A. Plumptre/WCS*

It is clear that Grauer's gorilla is critically threatened across its range. It is being effectively protected only in the highland sector of KBNP, while across most of the rest of its range it is declining rapidly. In the RGPU Grauer's gorilla is fairly protected simply by the remoteness of this region and the absence of militia groups, but this could quickly change. The occupancy results highlight that KBNP together with RGPU are critical for the survival of Grauer's gorilla with important populations persisting in Usala Forest, the Tayna and Kisimba-Ikobo Nature Reserves and Itombwe Reserve. Conservation efforts should, therefore, focus on these areas as priority sites for this species. Protecting these areas would also conserve the eastern chimpanzee (apart from the high altitude areas where it occurs at low density or is absent), but it appears that the lower altitude forests will also be important if they are remote from people.

The occupancy model produced a significant positive relationship between gorilla and chimpanzee occupancy and mining sites rather than a negative relationship. This is because mining sites are being established deep in the forest in remaining core habitat for the gorillas and, as such, they pose the greatest threat to the gorillas because of the associated bushmeat hunting. This is probably the most critical threat to both subspecies.

KEY INTERVENTIONS NEEDED TO HALT THE DECLINING POPULATIONS

If the remaining Grauer's gorilla and chimpanzee populations are to be protected and allowed to recover, several key interventions are required urgently:

- Artisanal mining sites need to be regulated, miners disarmed and weapons banned. Mines in national parks should be closed. Mines in community reserves need to be regulated and managed in a way that stops bushmeat consumption and develops a mechanism for villagers to sell alternatives foods to miners.
- The DRC Government must increase security in the region through its planned "green beret force", working closely with ICCN to expand patrol coverage across reserves and parks to allow ICCN and Community Reserve staff to operate without risk to their lives. Supporting wider patrolling will require funding, but is a means of employing some of the young men who would otherwise resort to mining or hunting to earn a living.
- There is an urgent need for legislation establishing the RGPU and Usala community reserves and to support protection efforts. There is also a need to complete the legal establishment of the Itombwe Reserve, which awaits only the signature of the Governor of South Kivu.
- Support is needed for community reserve management, particularly in Tayna, Usala, Kisimba-Ikobo and RGPU. This should include community benefits so that they begin to value the presence of the reserves.
- Increase awareness among local communities about the crisis gorillas, chimpanzees and elephants are facing, and work with Traditional Chiefs to put a taboo on hunting and eating of these species.
- Maintain habitat connectivity between key ape populations so that migration will be possible in future as populations recover.
- Identify and develop alternative ways of generating incomes in villages around key Grauer's gorilla areas so that there are other options to artisanal mining.
- The DRC Government needs to assist ICCN to re-settle people voluntarily outside Kahuzi-Biega and Maiko National Parks by providing greater incentives for them to move. If villagers are unwilling to be relocated voluntarily, at least zoning of the parks should occur so that the villages do not continue to expand.
- Increased funding is urgently needed to protect this species, the World's largest ape, if it is to survive in DRC. The decimation described here shows that the current level of funding is insufficient to halt the decline.

There is not much time left to implement these recommendations. At a rate of loss of 5% per annum, estimated from encounter rate data at sites where populations are declining rapidly, we will lose Grauer's gorilla from many of these sites during the next few (2–5) years.

Community awareness-raising of ape conservation issues, Penedjali, North Lowa. *Credit M. Vyalengerera*

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Lowland forest near Kilimamesa, Usala. *Credit S. Nixon*

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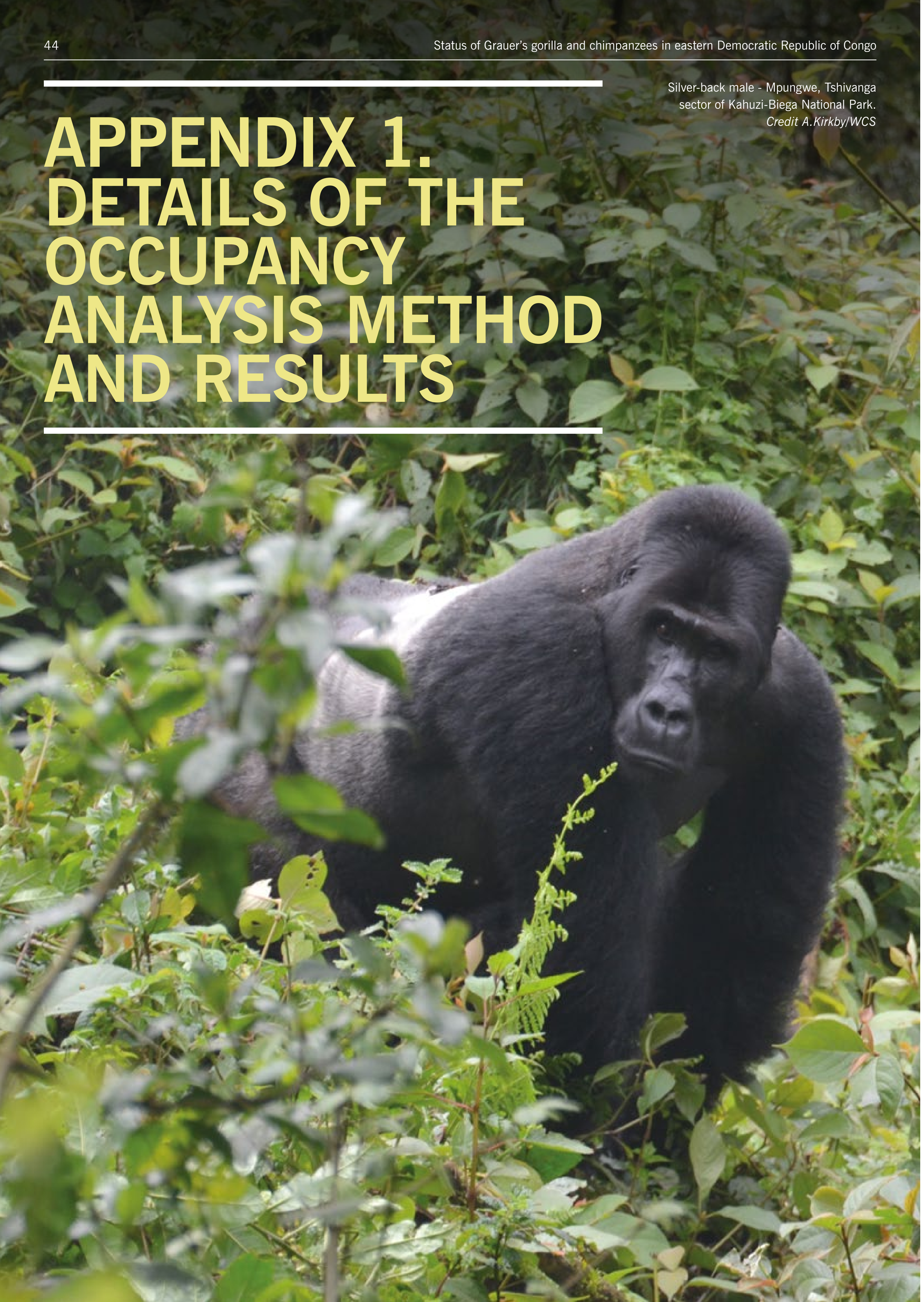

Silver-back male - Mpungwe, Tshivanga sector of Kahuzi-Biega National Park. *Credit A.Kirkby/WCS*

APPENDIX 1. DETAILS OF THE OCCUPANCY ANALYSIS METHOD AND RESULTS

The occupancy analysis we used in this report was the hSDM.ZIB.iCAR (a Zero Inflated Binomial model with spatial autocorrelation) model from the hSDM R package (Vieilledent *et al.* 2014). This model is hierarchical and structured as follows:

There is an ***ecological process*** – the suitability of the habitat:

$z_i \sim Bernoulli\ (\Theta_i)$

$Logit\ (\Theta_i) = X_i B + p_i$

Where z_i = habitat suitability at site *i*; Θ_i = probability that habitat is suitable at site *i*. Habitat at site *i* is described by environmental variables X_i with coefficients *B* and spatial random effect p_i. p_i is the spatial random effect for cell *i*.

Secondly there is a ***spatial auto-correlation*** component:

An intrinsic conditional autoregressive model (iCAR) is assumed:

$p_i = Normal\ (u_i, V_p/n_i)$

Where u_i = mean of p_i in the neighbourhood of cell *i*; V_p = variance of the spatial random effects; n_i = number of neighbours for cell *i*.

Thirdly there is an ***observation process:***

$y_i = Binomial\ (z_i * d_i, t_i)$

$Logit\ (d_i) = W_i \Upsilon$

Where y_i = presence of a species at site *i*; d_i = probability of detecting the species at site *i*; W_i = covariables explaining the observation process with parameters ϒ. t_i is the number of visits (trials) at site *i*.

Occupancy analysis normally uses repeated visits at the same site to be able to estimate a detection probability and avoid false absences. However, it is also possible to make repeat observations by replicating visits spatially. The entire 5x5 km cell could not be prospected and as a result there will have been false absences at some sites. In order to account for these false absences and estimate a detection probability, repeated spatial observations were necessary.

GORILLA MODEL

In the final hSDM.ZIB.iCAR model for gorillas the following coefficients for each covariable that were statistically significant and biologically relevant were obtained:

Covariable	Mean	SD	Significance
beta.(Intercept)	-4.074	0.449	P<0.05
beta.dem	1.237	0.313	P<0.05
beta.disforlos	1.233	0.419	P<0.05
beta.treecov	0.794	0.243	P<0.05
gamma. (Intercept)	-2.082	0.068	P<0.05
Vrho	9.391	0.563	
Deviance	798.779	15.572	

Gorillas tended to be found at higher elevations, where tree cover was high and away from active deforestation areas. Posterior mean detection probability (d_i) was 0.111 and the posterior mean probability of occupancy (Θ_i) was 0.073.

Comparison of deviance:
A comparison of the deviance values for the five models developed for gorillas is given here:

Model	Deviance	Percentage	
1 NULL	1126.6	0	No covariables
2 environment	1048.1	13	Tree cover and elevation
3 env+human impact	1029.3	17	Adding dist. to forest loss
4 env+hum+iCAR	798.8	56	Adding in iCAR
5 FULL	541.3	100	

CHIMPANZEE MODEL

In the final hSDM.ZIB.iCAR model for chimpanzees the following coefficients for each covariable were obtained:

	Mean	SD	Significance
beta.(Intercept)	–0.80933	0.346922	P<0.05
beta.bio2	–0.71862	0.301658	P<0.05
beta.dem	–0.77224	0.349159	P<0.05
beta.slope	0.476166	0.218128	P<0.05
beta.treecov	1.050568	0.258907	P<0.05
gamma.(Intercept)	–2.29037	0.058954	P<0.05
Vrho	9.389523	0.519067	
Deviance	1617.276	17.98489	

Chimpanzees were found where daily temperatures did not fluctuate greatly, at lower altitudes, away from steep slopes and where tree cover was high. Posterior mean detection probability (d_i) was 0.092 and the posterior mean probability of occupancy (Θ_i) was 0.431.

Comparison of deviance:
A comparison of the deviance values for the five models developed for chimpanzees is given here:

Model	Deviance	Percentage
1 NULL	1887.011	0
2 env	1775.86	16
3 env+hum	1775.86	16
4 env+hum+iCAR	1617.276	38
5 FULL	1184.636	100

Chimpanzee searching for fruits.
Credit A.Plumptre/WCS

ACKNOWLEDGEMENTS

Support for this analysis was primarily provided by the Arcus Foundation through the Jane Goodall Institute. Some of the surveys referred to in the report were funded by other donors, notably Critical Ecosystem Partnership Fund, the Disney Worldwide Conservation Fund, FZS, KfW, Rainforest Trust, UNESCO, USAID/CARPE, USFWS and World Bank. We are also grateful to all our field assistants, park wardens and rangers from ICCN, ecoguards working in the Community Reserves and the local inhabitants of the Usala region who were involved in the collection of data presented in this report. Hjalmar Kuehl, Sam Strindberg, Fiona Maisels and Lilian Pintea kindly provided advice on the methods and also some of the covariable layers. We are also grateful to Chester Zoo who supported the time of Stuart Nixon during the writing of this report, University of York who supported Rob Critchlow, and CIRAD who supported Ghislain Vieilledent to help with the R-analyses.