Mammal Review

Mammal Review ISSN 0305-1838

Editor's Choice

REVIEW, EDITOR'S CHOICE

Updated geographic range maps for giraffe, *Giraffa* spp., throughout sub-Saharan Africa, and implications of changing distributions for conservation

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Keywords
aerial survey, Africa, decline, endangered, geographic range, giraffe, spatial ecology

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Submitted: 24 May 2019
Returned for revision: 18 June 2019
Revision accepted: 19 June 2019
Editor: DR

doi: 10.1111/mam.12165

ABSTRACT

1. Giraffe populations have declined in abundance by almost 40% over the last three decades, and the geographic ranges of the species (previously believed to be one, now defined as four species) have been significantly reduced or altered. With substantial changes in land uses, loss of habitat, declining abundance, translocations, and data gaps, the existing geographic range maps for giraffe need to be updated.
2. We performed a review of existing giraffe range data, including aerial and ground observations of giraffe, existing geographic range maps, and available literature. The information we collected was discussed with and validated by subject-matter experts. Our updates may serve to correct inaccuracies or omissions in the baseline map, or may reflect actual changes in the distribution of giraffe.
3. Relative to the 2016 International Union for Conservation of Nature Red List Assessment range map, the updated geographic range maps show a 5.6% decline in the range area of all giraffe taxa combined. The ranges of *Giraffa camelopardalis* (northern giraffe) and *Giraffa tippelskirchi* (Masai giraffe) decreased in area by 37% (122432 km^2) and 4.7% (20816 km^2) respectively, whereas 14% (41696 km^2) of the range of *Giraffa reticulata* (reticulated giraffe) had not been included in the original geographic range map and has now been added. The range of *Giraffa giraffa* (southern giraffe) showed little overall change; it increased by 0.1% (419 km^2).
4. Ranges were larger than previously reported in six of the 21 range countries (Botswana, Ethiopia, Mozambique, South Sudan, Tanzania, and Zimbabwe), had declined in seven (Cameroon, Central African Republic, Chad, Malawi, Niger, Uganda, and Zambia) and remained unchanged in seven (Angola, Democratic Republic of Congo, eSwatini, Namibia, Rwanda, Somalia, and South Africa).
5. In Kenya, the ranges of both *Giraffa tippelskirchi* and *Giraffa camelopardalis* decreased, but the range of *Giraffa reticulata* was larger than previously believed.
6. Our updated range maps increase existing knowledge, and are important for conservation planning for giraffe. However, since rapid infrastructure development throughout much of Africa is a driver of giraffe population declines, there is an urgent need for a continent-wide, consistent and systematic giraffe survey to produce more accurate range maps, in order to inform conservation and policy planning.

INTRODUCTION

Giraffe (*Giraffa* spp.) are vital to ecosystem function, as they disperse seeds, create open habitat, stimulate the growth of new forage, and indirectly pollinate various plants during foraging activities (Muller et al. 2018). Recent genetic analyses suggest that instead of a single species, giraffe may be comprised of four separate and distinct species (Fennessy et al. 2016a) – *Giraffa camelopardalis* (northern giraffe), *Giraffa giraffa* (southern giraffe), *Giraffa reticulata* (reticulated giraffe), and *Giraffa tippelskirchi* (Masai giraffe) – that have become adapted to an array of habitats from arid deserts to acacia (*Vachellia* and *Senegalia*) woodlands and savannahs (Fennessy et al. 2016a, Winter et al. 2018). Fennessy et al. (2016a) also proposed five subspecies of giraffe: *Giraffa giraffa angolensis* (Angolan giraffe), *Giraffa giraffa giraffa* (South African giraffe), *Giraffa camelopardalis camelopardalis* (Nubian giraffe), *Giraffa camelopardalis antiquorum* (Kordofan giraffe), and *Giraffa camelopardalis peralta* (West African giraffe).

The International Union for Conservation of Nature (IUCN) Red List Assessment for giraffe (Muller et al. 2018) and subsequent IUCN Red List Assessments for giraffe subspecies (various authors, see Table 1) use one species: *Giraffa camelopardalis* (giraffe), with nine subspecies: *Giraffa camelopardalis peralta* (West African giraffe), *Giraffa camelopardalis antiquorum* (Kordofan giraffe), *Giraffa camelopardalis camelopardalis* (Nubian giraffe), *Giraffa camelopardalis reticulata* (reticulated giraffe), *Giraffa camelopardalis rothschildi*

Table 1. The updated giraffe taxonomy that is adopted in this paper, the taxonomy used in the IUCN Red List assessment for the giraffe (single species), and the Red List category for each taxon. The category for the species *Giraffa camelopardalis* is Vulnerable. Fennessy et al. (2016a) identified four species, of which two – *Giraffa camelopardalis* (northern giraffe), and *Giraffa giraffa* (southern giraffe) – have subspecies.

Updated giraffe taxonomy (Fennessy et al. 2016a, Winter et al. 2018)	IUCN Red List taxonomy (Muller et al. 2018)	IUCN Red List Category
Giraffa camelopardalis peralta (West African giraffe)	*Giraffa camelopardalis peralta* (West African giraffe)	Vulnerable (Fennessy et al. 2018a)
Giraffa camelopardalis antiquorum (Kordofan giraffe)	*Giraffa camelopardalis antiquorum* (Kordofan giraffe)	Critically Endangered (Fennessy & Marais 2018)
Giraffa camelopardalis camelopardalis (Nubian giraffe)	*Giraffa camelopardalis camelopardalis* (Nubian giraffe)	Critically Endangered (Wube et al. 2018)
Giraffa camelopardalis camelopardalis (Nubian giraffe)	*Giraffa camelopardalis rothschildi* (Rothschild's giraffe)	Near Threatened (Fennessy et al. 2018b)
Giraffa reticulata (reticulated giraffe)	*Giraffa camelopardalis reticulata* (reticulated giraffe)	Endangered (Muneza et al. 2018)
Giraffa tippelskirchi (Masai giraffe)	*Giraffa camelopardalis tippelskirchi* (Masai giraffe)	Endangered (Bolger et al. 2019)
	Giraffa camelopardalis thornicrofti (Thornicroft's giraffe)	Vulnerable (Bercovitch et al. 2018)
Giraffa giraffa angolensis (Angolan giraffe)	*Giraffa camelopardalis angolensis* (Angolan giraffe)	Least Concern (Marais et al. 2018)
Giraffa giraffa giraffa (South African giraffe)	*Giraffa camelopardalis giraffa* (South African giraffe)	Not assessed separately.

(Rothschild's giraffe), *Giraffa camelopardalis tippelskirchi* (Masai giraffe), *Giraffa camelopardalis thornicrofti* (Thornicroft's giraffe), *Giraffa camelopardalis angolensis* (Angolan giraffe), and *Giraffa camelopardalis giraffa* (South African giraffe).

Giraffe taxonomy has long been unresolved (Shorrocks 2016), and there is an ongoing debate about the proposed updated taxonomy (Bercovitch et al. 2017, Fennessy et al. 2017, Winter et al. 2018). However, we decided to use the updated taxonomy proposed by Fennessy et al. (2016a), as it is based on the most in-depth analysis of genetic evidence and gene flow from wild giraffe throughout Africa to date (Table 1).

Throughout the African continent, many giraffe populations are declining in abundance, and giraffe are now absent from much of their historical geographic ranges. Combined, giraffe populations have declined by approximately 40% in the past 30 years alone, resulting in the recent change of category for the species *Giraffa camelopardalis* from Least Concern to Vulnerable on the IUCN Red List of Threatened Species (Muller et al. 2018; Table 1).

Two subspecies of giraffe, *Giraffa camelopardalis antiquorum* and *Giraffa camelopardalis camelopardalis*, are now restricted to small fragmented populations in nine countries in the northern half of Africa, and were officially listed as Critically Endangered on the IUCN Red List in 2018 (Fennessy & Marais 2018, Wube et al. 2018). The conservation status of two other species, *Giraffa reticulata* and *Giraffa tippelskirchi*, were also recently changed from Vulnerable to Endangered on the IUCN Red List (Muneza et al. 2018, Bolger et al. 2019). The range of *Giraffa reticulata* is now restricted to northern Kenya and parts of Ethiopia and Somalia, whereas *Giraffa tippelskirchi* is now found only in southern Kenya, Tanzania, and the Luangwa Valley in eastern Zambia (Berry & Bercovitch 2017).

The rapid decline in many giraffe populations and the reduction in the species' geographic range is widely attributed to habitat loss, land degradation, climate change, and illegal poaching, all of which have significantly altered and reduced the geographic range of giraffe throughout Africa (Muller et al. 2018). Giraffe historically existed largely outside of public and private protected lands, and thus directly overlapped with human activities, such as agriculture and livestock rearing (Ogutu et al. 2016). However, as natural spaces continue to shrink or become increasingly degraded, giraffe are becoming restricted to formally recognised protected areas. Yet, these protected areas may be too small to support viable giraffe populations and are also becoming increasingly isolated due to urban development, infrastructure, and human settlement, further fragmenting giraffe populations (Newmark 2008). Projections indicate that the human population in Africa will double by 2050, so giraffe habitat is likely to continue to be impacted by anthropogenic alterations (Dos Santos et al. 2017). Giraffe have already been extirpated in at least seven countries in the last century (Burkina Faso, Eritrea, Guinea, Mali, Mauritania, Nigeria, and Senegal), and much of their remaining geographic range is becoming increasingly fragmented (Fennessy et al. 2016b,

Shorrocks 2016). Understanding the impacts of sustained human population growth on the continued range restriction of giraffe is vital for conservation efforts.

Despite their iconic stature, giraffe suffer from a lack of scientific research, which has been a major concern and challenge for mapping their geographic distribution and designing conservation strategies (Fennessy 2008). Much of giraffe ecology has remained relatively understudied, including distribution, abundance, and occupancy. Understanding the distribution of giraffe and their habitat is essential for the development and maintenance of reserves and for the development of animal movement corridors, while also providing baseline information for assessing changes over time and insight into the factors driving those changes (Borghi et al. 2011). Accurate distribution estimates are important for highlighting where further conservation and management is necessary, especially in giraffe range countries where populations are isolated and disconnected.

Historically, giraffe geographic range maps have varied greatly between sources, ranging from a coarse view characterised by a wide geographic distribution across most sub-Saharan countries to granular depictions with only small fragmented pockets in West, East, and Southern Africa (Fennessy 2004, Shorrocks 2016). Overall, the 2016 IUCN Red List Assessment of the geographic range of giraffe requires an update to incorporate direct observational data and the most up-to-date information on the species (Fennessy 2008, Giraffe Conservation Foundation 2016, Muller et al. 2018).

We present new, comprehensive geographic range maps for giraffe throughout Africa and discuss the implications of the distribution for the conservation of the taxa. We utilised new data and information from aerial and ground observations, from the available literature, and from subject-matter experts, to update the 2016 IUCN Red List giraffe range map (Giraffe Conservation Foundation 2016, Muller et al. 2018). We also examined the distribution of giraffe throughout government-managed protected areas (GMPAs), in order to determine potential impacts of protected areas on giraffe conservation efforts.

METHODS

We obtained information on the current geographical range of giraffe from a variety of sources. We combined aerial and ground survey observations, movement data from Global Positioning System (GPS) telemetry, existing geographic range maps, data from a literature review, and information from various regional experts to provide the most up-to-date and accurate geographic range maps (see Appendix S1). We used the 2016 IUCN Red List giraffe range map (Giraffe Conservation Foundation 2016, Muller et al. 2018) as the baseline for this update (Fig. 1). Our updates may serve to correct inaccuracies or omissions in the baseline map, or may reflect actual changes in the distribution of giraffe, due to movements, range changes, or changes in numbers. We cannot distinguish between these possibilities, and report only our best estimates of geographic ranges.

Aerial observation survey data

The main continent-wide source of data used for this update was a series of aerial observations of giraffe recorded during the Great Elephant Census (GEC), a Paul G. Allen Project, designed to survey *Loxodonta africana* (African savannah elephants) and other large mammals, including giraffe, throughout approximately 90% of known *Loxodonta africana* range. In 2014–2015, a systematic aerial survey (primarily total and sample counts) was conducted throughout 18 countries according to standardised protocols for aerial total and sample counts (described by Chase et al. 2016). For this study, we accessed giraffe observation data for 10 of the survey countries: Angola, Botswana, Cameroon, Chad, Ethiopia, Kenya, Mozambique, South Sudan, Tanzania, and Zimbabwe.

We also used giraffe observational data from aerial surveys conducted by the Kenya Wildlife Service in November 2017 (Ngene et al. 2018). These surveys, designed similarly to the GEC, were conducted by flying transects within standardised survey blocks in Laikipia, Isiolo, Marsabit, Meru, and Samburu counties of northern Kenya. Giraffe observed during the surveys were recorded, and the GPS locations of the observations were incorporated into this update.

Images of giraffe distribution derived from observations of giraffe during aerial surveys throughout key areas of northern Central African Republic, South Sudan, and Ethiopia were also included in this update (Fay et al. 2007, Grossmann et al. 2008, 2011, Monico & Schapira 2015, Elkan et al. 2016a, b, 2017, P. Elkan 2018, unpublished data).

Ground observation survey data

We incorporated observational data collected during the Great Grevy's Rally (GGR), a biennial census of *Equus grevyi* (Grevy's zebra) and *Giraffa reticulata* in which approximately 700 citizen scientists recorded GPS observations of giraffe (Rubenstein et al. 2018). The rally took place in January 2018 throughout five counties in northern Kenya (Laikipia, Isiolo, Marsabit, Meru, and Samburu). The GPS coordinates of all giraffe observations from the rally were incorporated into this update.

The Northern Rangelands Trust Wildlife-Conservancy Management Monitoring System (Wildlife-CoMMS) rangers also provided GPS observation data for giraffe,

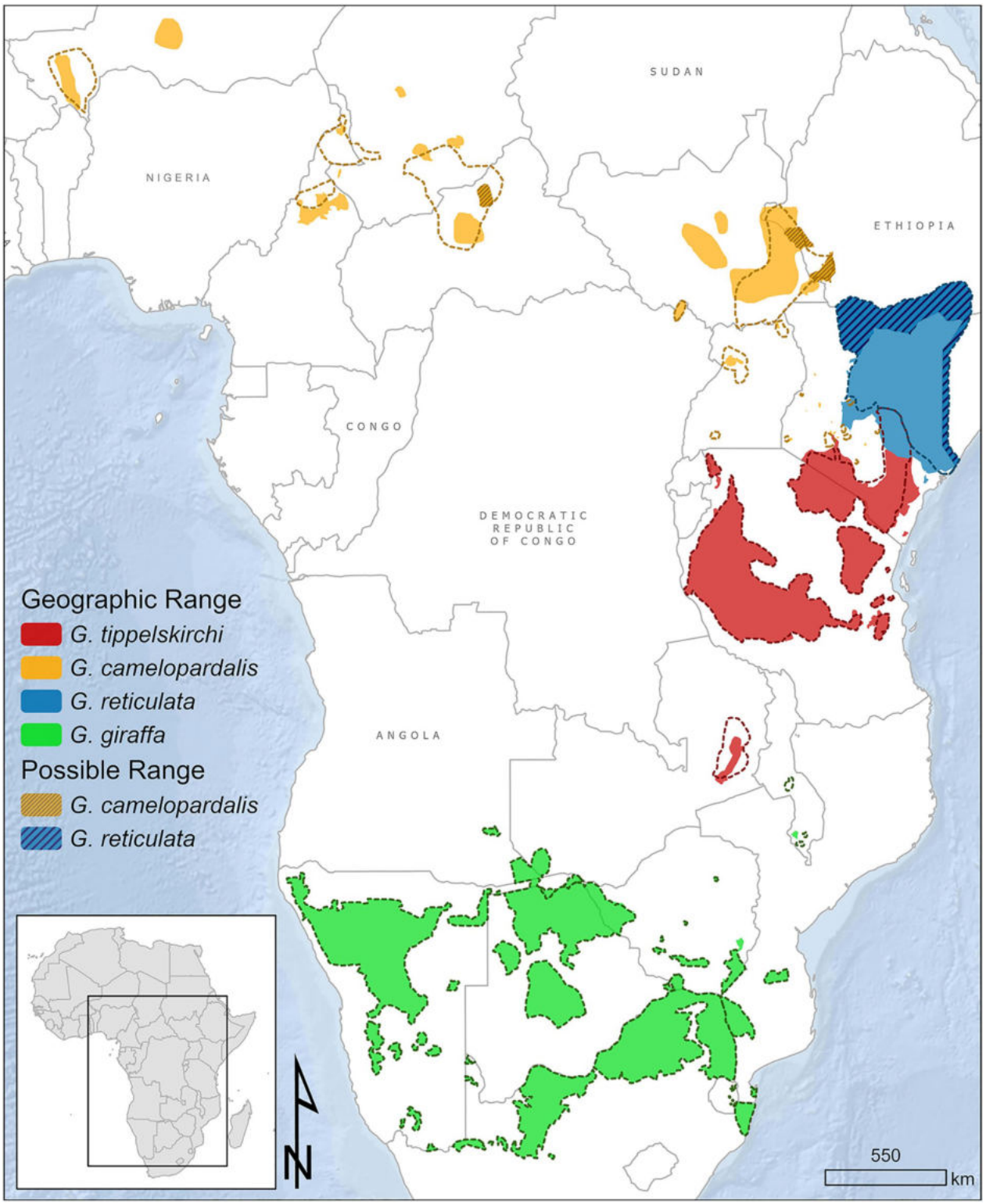

Fig. 1. Updated geographic range maps for giraffe in sub-Saharan Africa. Ranges are shown as filled coloured polygons for each species. The dashed outlines show the previously recognised IUCN range for each taxon (Giraffe Conservation Foundation 2016, Muller et al. 2018). The cross-hatched areas are where giraffe populations are not confirmed, but possibly do occur. See Appendices S1 and S4 for data sources and details of range changes. [Colour figure can be viewed at wileyonlinelibrary.com]

collected during routine monitoring surveys, as did the Twiga Walinzi giraffe research team based in northern Kenya (A. Wandera, personal communication; D. O'Connor, unpublished data).

In Niger, long-term population monitoring and observation data, provided and collected by Giraffe Conservation Foundation (GCF), Sahara Conservation Fund, the Niger Government and others also contributed to this update. Likewise, for the Uganda giraffe range updates, we incorporated giraffe population monitoring and observation data collected by a collaborative effort by Uganda Wildlife Authority, GCF and Dartmouth University. Observation data from the Zambian Carnivore Programme and Northern Michigan University were provided to update the range of *Giraffa tippelskirchi* in Zambia.

Satellite-derived GPS telemetry data

We used location data acquired from giraffe fitted with satellite tracking devices in northern Kenya and in Uganda. In northern Kenya, giraffe were observed in areas outside the baseline geographic distribution map. During June 2017, 11 individuals of *Giraffa reticulata* were fitted with solar-powered GPS tracking units, built and designed by Savannah Tracking (Nairobi, Kenya), and affixed to the ossicone of each giraffe. Each unit was set to collect hourly positions. For this range update, we compiled all of the hourly GPS locations recorded from June 2017 to November 2018.

In Uganda, *Giraffa camelopardalis* movements were monitored as part of a larger study on giraffe spatial ecology throughout the country. In January 2016, five giraffe were equipped with head-harness GPS units (African Wildlife Tracking, Pretoria, South Africa) as part of a post-translocation monitoring programme wherein giraffe were captured on the northern banks of the Nile River, in Murchison Falls National Park, and released in southern Murchison Falls National Park. In southern Murchison Falls National Park, giraffe were tracked from January 2016 to January 2018, with hourly positions. We also collected location data from five solar-powered ossicone-mounted GPS units (Savannah Tracking, Nairobi, Kenya) deployed in Kidepo Valley National Park in April 2018. For the Kidepo Valley National Park population, we generated a minimum convex polygon around all hourly GPS locations from April 2018 to June 2018.

Literature review

We reviewed the available literature on giraffe distribution by exhaustively searching the Giraffe Resource Centre (www.girafferesourcecentre.org), Web of Science, and Google Scholar for relevant available literature, observation data, or existing baseline geographic range maps. We used the following search terms: 'giraffe' or 'giraffa' combined with 'distribution', 'conservation', 'range', 'biogeography', or 'range extension'.

Expert knowledge

We consulted various experts to ensure that the updated maps we produced were as accurate as possible, and to clarify the distribution in areas where giraffe are known to occur but no published data are available (Appendix S1). To accomplish this, we provided draft giraffe range maps to regional experts, wildlife authorities, conservancy managers, and researchers ($n = 26$), and asked each person to either verify giraffe range within the area, or redraw the range based on their recent observations and knowledge.

In addition, we interviewed researchers and personnel involved with translocations of giraffe since 2017 in several countries including Malawi, Niger, and Uganda. In most scenarios, the translocated giraffe had been moved into fenced or protected areas. In these cases, we extended the geographic range maps to the boundaries of the conservation areas where the giraffe had been released. If the giraffe had not been moved into a fenced area, we redrew the geographic range based on input provided by the experts.

Mapping methods and protected areas

We used ArcMap 10.6 (ESRI, Redlands, CA, USA) for mapping ranges. We generated updated range maps by incorporating the data obtained by all methods described above, plotting the data and attenuating or extending range outlines as required. In total, we obtained information, data and/or expert information on giraffe ranges for all 21 countries highlighted in the original, baseline IUCN range map (aerial survey data for 11 countries, ground observation data on four countries, and expert knowledge for all countries, see Appendix S1).

We only reduced ranges when experts could confirm that giraffe are absent in a particular area. Otherwise, we defined areas where giraffe persistence was possible, but empirical data were unavailable to substantiate it, as 'possible ranges' (Fig. 1). Geographic ranges were not updated for South Africa, as giraffe exist there within numerous independent private ranches, many of which are likely to be outside the species' natural and historical range.

To provide a better understanding of the role of formally protected areas on giraffe populations, our updated giraffe range map was overlaid on top of a map derived from the World Database on Protected Areas (WDPA; UNEP-WCMC & IUCN 2019). We only included areas with a governance type of 'governance by government'

or 'shared governance'. These GMPAs include Biological Reserves, Game Management Areas, Game Reserves, and National Parks (see full list in Appendix S2). We left out areas with a governance type of 'private governance' or 'governance by indigenous peoples and local communities' (Alternative Governance Protected Areas), as we felt that this dataset may not be fully inclusive of all private lands in Africa, and that the management of these areas could vary greatly from site to site. We estimated the percentage of giraffe geographic range area that overlapped with GMPAs, by totalling the protected areas within giraffe ranges for comparison with the total range area of giraffe.

RESULTS

We produced an updated geographic range map for giraffe (Fig. 1, Appendices S3 and S4), based on observation, telemetry and literature data and expert knowledge, that improves the accuracy of the original IUCN Red List Assessment map (Giraffe Conservation Foundation 2016, Muller et al. 2018) and highlights the range of each of the four proposed giraffe species (Fennessy et al. 2016a, Winter et al. 2018). We observed a net positive change in overall giraffe geographic range area in seven of 21 countries (Botswana, Ethiopia, Kenya [*Giraffa reticulata*], Mozambique, South Sudan, Tanzania, and Zimbabwe), and a net negative change in eight others (Cameroon, Central African Republic, Chad, Kenya [*Giraffa camelopardalis* and *Giraffa tippelskirchi*], Malawi, Niger, Uganda, and Zambia). Some countries (e.g. Niger) showed overall declines in the range area, but at the same time featured new locations occupied by giraffe, because recent translocations have resulted in new, reintroduced or newly established populations (Giraffe Conservation Foundation 2018). Thus, new range extensions were observed in many countries (Fig. 1, Appendices S3 and S4). Giraffe ranges remained unaltered in three countries (Angola, Democratic Republic of Congo, and Rwanda). Four additional countries had insufficient data and also remained unaltered (eSwatini [formerly Swaziland], Namibia, Somalia, and South Africa).

We found an overall decline of 5.6% in the geographic range area of giraffe. For some species, the geographic range area was greatly reduced (e.g. *Giraffa camelopardalis*, −37%) or increased (e.g. *Giraffa reticulata*, +14%), whereas others changed little in net area (Table 2, Fig. 2). Changes also varied by country (Table 3, Appendix S3). Approximately 29% of giraffe range occurred in GMPAs (Table 2). Figure 3 shows the parts of the giraffe geographic ranges that include these protected areas, and Appendix S4 provides a summary of the changes made as a result of this study. Our literature search resulted in 69 relevant papers; however, none provided novel information that we had not already procured through other methods.

Giraffa camelopardalis

The geographic range of *Giraffa camelopardalis* spans nine countries, including from southwestern Niger through parts of Chad, northern Cameroon, Central African Republic, South Sudan, Democratic Republic of Congo, Ethiopia, and Uganda; small populations occur in western Kenya. *Giraffa camelopardalis* occurs discontinuously throughout much of its range. We extended parts of the existing range maps in Ethiopia, Niger, Chad, South Sudan, and Uganda, and reduced the existing range in Cameroon, Central African Republic, Democratic Republic of Congo, and Kenya. Additional data, however, are necessary to confirm the presence of *Giraffa camelopardalis* in all previously known areas. These areas were thus categorised as 'possible' parts of the species' range (Fig. 2a).

The updated range resulted in a ~37% decline in the total range area of *Giraffa camelopardalis*. In addition, ~25% of its geographic distribution now occurs in GMPAs, compared with 14% previously. In Kenya and Uganda, the geographic range of this species now occurs almost entirely within GMPAs (Fig. 3).

Table 2. Summary of the total area of the previously recognised range and updated geographic range for all giraffe species, the approximate percentage of the range occurring within GMPAs, and the percentage change in range as a result of this update. See also Figs 2 and 3, and Appendix S5.

	Previously recognised IUCN range		Updated geographic range		
Species	Approximate area of range (km^2)	Approximate area of range within GMPAs (%)	Approximate area of range (km^2)	Approximate area of range within GMPAs (%)	Overall change in range area (%)
Giraffa camelopardalis	334144	14	211712	25	−37
Giraffa giraffa	730931	25	731350	25	0
Giraffa reticulata	308135	3	349831	4	14
Giraffa tippelskirchi	444970	60	424154	59	−5
Total	1818180	28	1717047	29	−6

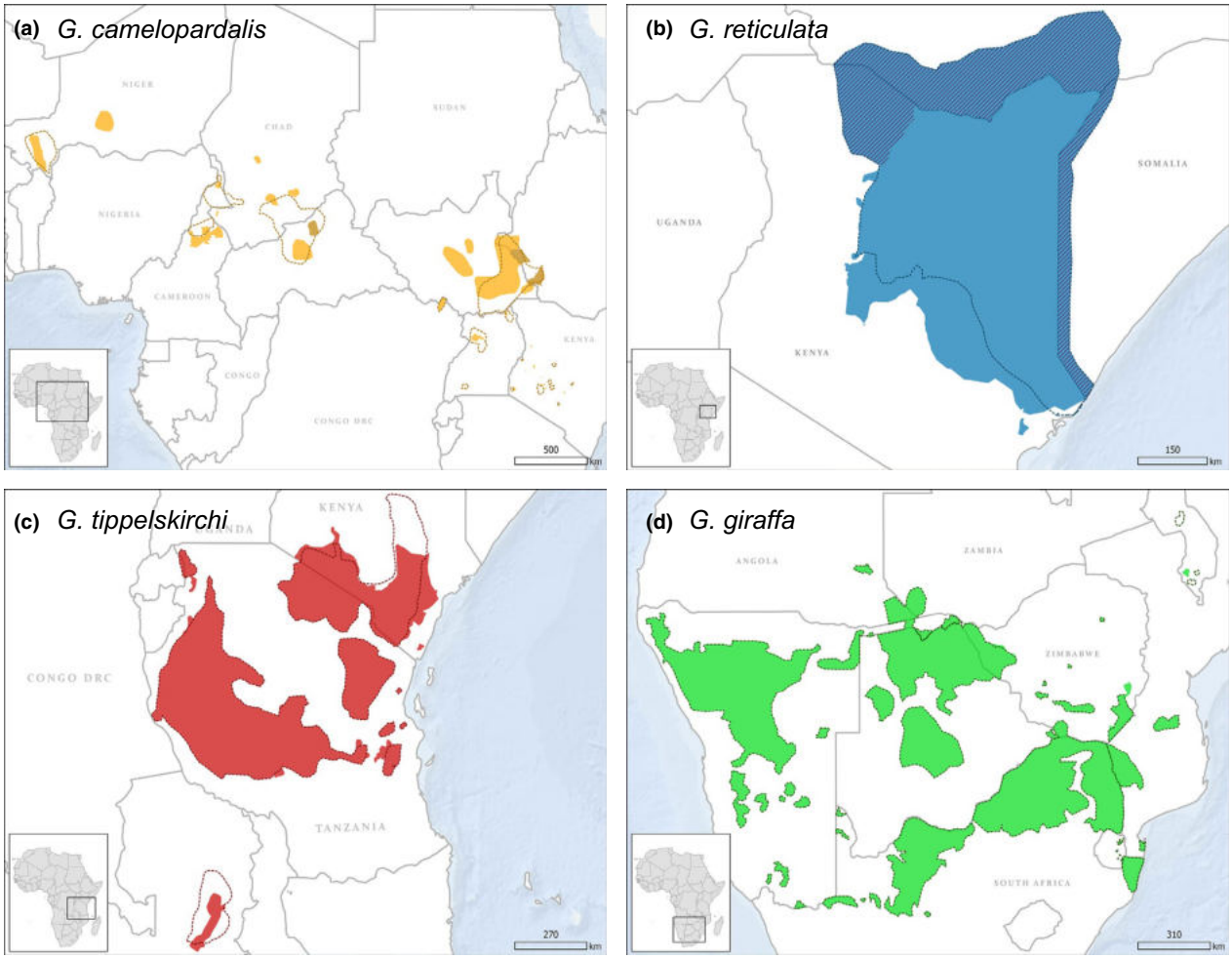

Fig. 2. Updated range map for each of the four giraffe species in sub-Saharan Africa. Ranges are shown as coloured polygons for: (a) *Giraffa camelopardalis,* (b) *Giraffa reticulata*, (c) *Giraffa tippelskirchi*, and (d) *Giraffa giraffa*. The dashed outlines show the previously recognised IUCN ranges (Giraffe Conservation Foundation 2016, Muller et al. 2018). Cross-hatched areas are where giraffe populations are not confirmed, but possibly do occur. See Appendices S1 and S4 for data sources and details of range changes. [Colour figure can be viewed at wileyonlinelibrary.com]

Giraffa reticulata

The geographic range of *Giraffa reticulata* extends throughout much of northern Kenya; small fragmented populations are still likely to occur in southern Ethiopia and western Somalia. The updated map resulted in a 14% extension to the range area of *Giraffa reticulata*, as part of the range that was omitted from the original range map has now been added. The updated range map shows that just 4.2% of the *Giraffa reticulata* range occurs within GMPAs (Table 2, Fig. 3).

The updated geographic range of *Giraffa reticulata* expands significantly south and southeast from the baseline map; there are smaller extensions along the eastern boundary of the range (Fig. 2b). Although the populations are shown as connected, it is unclear whether the giraffe population near Lake Turkana is isolated from or connected to populations in the rest of the range. Further data and observations are needed to clarify the extent of the range in this area. There is also an isolated population of *Giraffa reticulata* in Mwingi National Reserve. However, this population is not shown in the updated range map (Fig. 2b), as we were unable to delineate its range with sufficient accuracy. Further observations and information are needed to understand giraffe movements and occupancy in this region.

Giraffa tippelskirchi

The updated geographic range of *Giraffa tippelskirchi* extends throughout southern Kenya and much of Tanzania, and extends slightly into Rwanda; there is a small disjointed population occurring in Zambia. In Kenya, the range has

Table 3. Summary of the total geographic range area for giraffe species by country, and the percentage change in range as a result of this update. See Appendix S3.

Country	Species	Previously recognised IUCN range area (km^2)	Updated geographic range area (km^2)	Overall change in range area (%)
Angola	*Giraffa giraffa*	10667	10667	0
Botswana	*Giraffa giraffa*	164232	164283	0
Cameroon	*Giraffa camelopardalis*	35012	17407	–50
Central African Republic	*Giraffa camelopardalis*	65344	21780	–67
Chad	*Giraffa camelopardalis*	55639	9589	–83
Democratic Republic of Congo	*Giraffa camelopardalis*	2885	2885	0
eSwatini	*Giraffa giraffa*	403	403	0
Ethiopia	*Giraffa reticulata*	94837	95549	1
Kenya	*Giraffa camelopardalis*	4670	1178	–75
	Giraffa reticulata	220464	262202	19
	Giraffa tippelskirchi	92705	86172	–7
Malawi	*Giraffa giraffa*	2510	701	–72
Mozambique	*Giraffa giraffa*	21840	21938	0
Namibia	*Giraffa giraffa*	228649	228649	0
Niger	*Giraffa camelopardalis*	37702	28380	–25
Rwanda	*Giraffa tippelskirchi*	891	891	0
Somalia	*Giraffa reticulata*	20669	20669	0
South Africa	*Giraffa giraffa*	255420	255420	0
South Sudan	*Giraffa camelopardalis*	89004	98989	11
Tanzania	*Giraffa tippelskirchi*	322313	327732	2
Uganda	*Giraffa camelopardalis*	15879	2920	–82
Zambia	*Giraffa tippelskirchi*	29061	9359	–68
	Giraffa giraffa	8076	8076	0
Zimbabwe	*Giraffa giraffa*	39062	41141	5

been extended northward to just west of Nairobi and eastward towards Mombasa, but the northernmost portion of the range was reduced to the south. In Tanzania, the range of *Giraffa tippelskirchi* has been slightly extended near Selous Game Reserve and to the south near Lake Victoria (Fig. 2c). With more data from long-term studies, the estimated range has also been reduced overall in the Luangwa Valley, Zambia; however, further observations and information are needed to understand giraffe movements, occupancy, and better define range in this region (Fig. 2c).

These changes resulted in a ~4.7% decline in the geographic range area of *Giraffa tippelskirchi*; 59% of the range occurs in GMPAs (Table 2, Fig. 3).

Giraffa giraffa

The geographic range of *Giraffa giraffa* extends from south-eastern Angola, throughout Namibia, Botswana, South Africa, eSwatini, and into parts of Zimbabwe, Mozambique, Zambia, and Malawi. The updated geographic range has been extended slightly in western and south-eastern Zimbabwe, central Botswana, and western Mozambique. However, the geographic range in Malawi has been reduced to encompass three small disjointed populations in the southern part of the country.

The updated range of *Giraffa giraffa* is increased by 0.1%; 25% of the range occurs in GMPAs (Table 2, Fig. 3). The biggest change (−72%, Table 3) to the geographic range of *Giraffa giraffa* occurred in Malawi.

DISCUSSION

Our findings demonstrate that, although giraffe are one of the most iconic and recognisable animals, the 2016 IUCN Red List Assessment giraffe range map (Giraffe Conservation Foundation 2016, Muller et al. 2018) required an update. We have produced the most comprehensive and accurate geographical range map for giraffe in sub-Saharan Africa to date (Fig. 1).

The new range of *Giraffa camelopardalis* presented here shows that fragmented populations exist in Uganda, Kenya, Ethiopia, and Chad; much range reduction has occurred as a result of human-driven habitat loss or degradation, potentially exacerbated by climate change. The range expansions are a result of recent translocations into GMPAs where giraffe had been extirpated. These fragmented populations highlight critical declines and conservation challenges for many giraffe populations throughout northern Africa.

The updated geographic range of *Giraffa reticulata* in Kenya was significantly larger than the formerly recognised

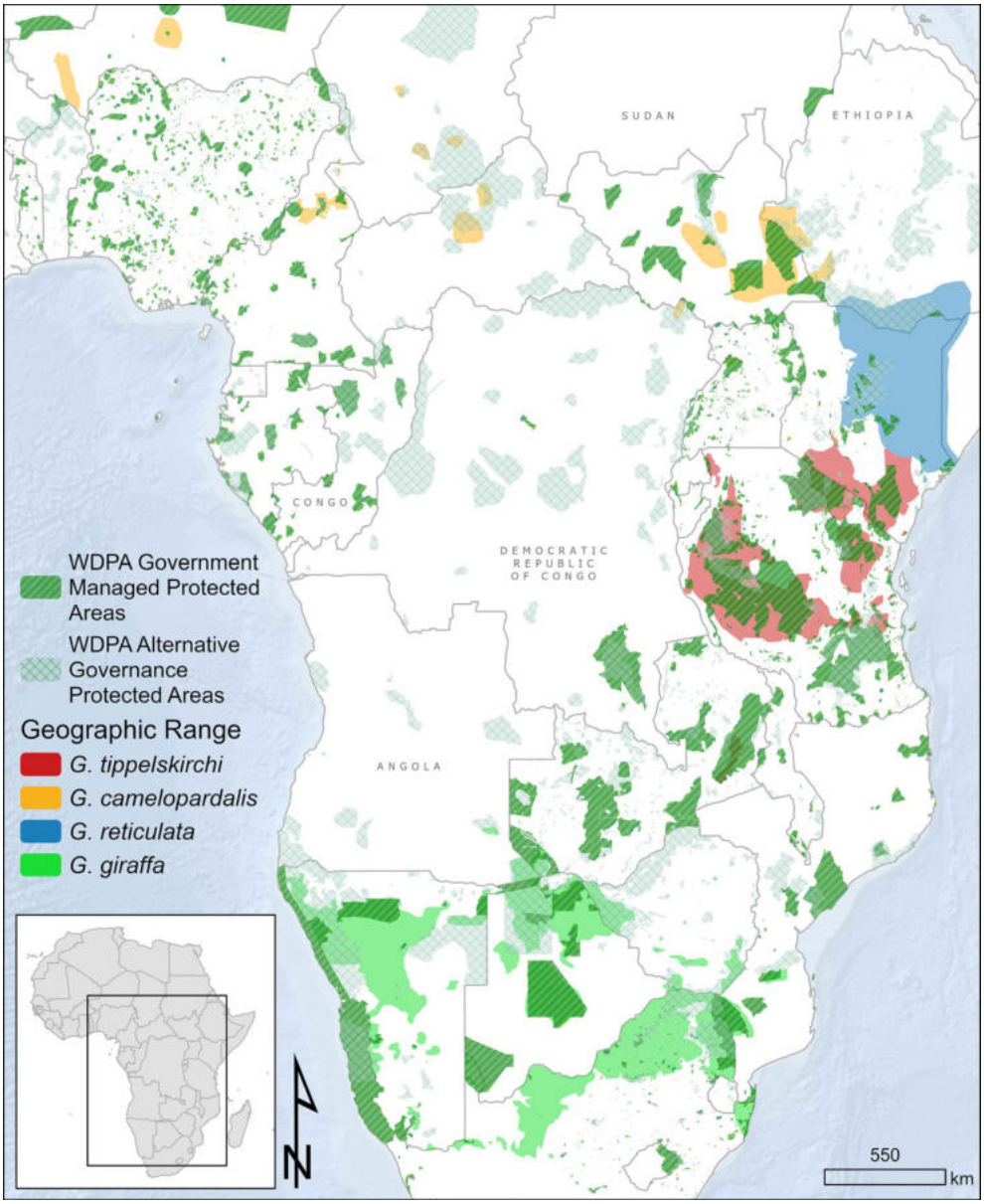

Fig. 3. Government-managed protected areas (GMPAs; shown by the cross-hatched areas) and alternative governance protected areas (shown by the double cross-hatched areas) in relation to the geographic ranges of giraffe (including areas where they possibly occur). GMPAs have a governance type of 'governance by government' or 'shared governance' in the World Database on Protected Areas (WDPA; UNEP-WCMC and IUCN 2019). [Colour figure can be viewed at wileyonlinelibrary.com]

range, and now extends much further to the south and southwest than previously indicated. This increase is unlikely to be due to a range expansion or a population increase, but is probably due to the inclusion of improved data from survey and monitoring efforts.

Roughly 70% of the current geographic range of giraffe occurs outside GMPAs, where much of the habitat has been greatly impacted by urban development, increased agriculture, and livestock overgrazing (Dos Santos et al. 2017). Such continued habitat loss and encroachment will lead to giraffe being confined to isolated, unconnected populations within GMPAs, as is the case in Uganda for example (Brown et al. in press). However, community-owned and privately-owned reserves and conservancies such as those in northern Kenya, where 95% of *Giraffa reticulata* range occurs outside GMPAs (Table 2, Fig. 3) have been successful in preserving giraffe habitats and connectivity in the region, by increasing security and anti-poaching efforts,

protecting habitat, and raising awareness among local communities. In addition, understanding how pastoral people, livestock, and giraffe can co-exist within these shared conservancy lands will be a vital tool for future conservation efforts aimed at managing the use of shared resources and spaces by all user groups (Weston & Ssemakula 1981, O'Connor et al. 2015, 2016, Ogutu et al. 2016, Veldhuis et al. 2019). While GMPAs often play a critical role in conservation efforts, they cannot act alone. It is impossible to preserve enough viable giraffe populations in GMPAs, given their limited number and extent, and given limited government resources. In addition to GMPAs, well managed, coordinated community and private-sector land management for conservation and people are critical for sustainable, viable, connected giraffe populations (Naidoo et al. 2011, Lindsey et al. 2012, Fitzgerald 2014, Ogutu et al. 2017, Galvin et al. 2018, Lee 2018). For example, although our analysis indicates that approximately 60% of *Giraffa tippelskirchi* range occurs within GMPAs, populations of this species have faced drastic population declines in recent decades (Bolger et al. 2019). Developing specific strategies aimed at conserving and managing giraffe populations within GMPAs will be critical, especially as more populations become restricted within the boundaries of these protected areas. With limited knowledge of giraffe geographic distribution and ecology, it is difficult to understand the implications this can have on their populations, and how the connectivity of protected areas could be improved (Fennessy et al. 2016b). Further research to understand the importance of GMPAs, community reserves, and private reserves for the conservation of giraffe would be interesting and valuable for driving targeted conservation actions.

Landscape features, such as physical and geographical barriers, human infrastructure and settlements, are not included in this review, but it is likely that the actual distribution of giraffe is fragmented further where such features occur. In southern Kenya in the last decade, urban areas and demand for land for livestock farming have increased, leading to constrictions in the range of wildlife (Ogutu et al. 2016). Kajiado County alone has over one million human inhabitants spread over 21900 km^2, and industrial development, massive housing development, quarrying and mining projects have increasingly contributed to subdivision and fragmentation of land, resulting in a decrease in forests and grasslands, and an increase in barelands (County Government of Kajiado 2018). All these factors continue to threaten important dispersal areas for *Giraffa tippelskirchi*, primarily through the building of fences, habitat loss, and negative interactions between people and giraffe. However, in order to help address these threats, local governments in Kenya have recently started to develop Spatial Management Plans to preserve key conservation areas and address unplanned subdividing and fencing of land (County of Government of Kajiado 2018).

In certain countries, giraffe populations are relatively small, isolated, and disconnected, because giraffe have been extirpated from large parts of their former ranges, as shown by historical range maps recently compiled by Giraffe Conservation Foundation (Appendix S5). To improve the likelihood of viable giraffe populations in these countries surviving into the future, giraffe have been successfully translocated and reintroduced to their former ranges, for example in Malawi, Namibia, Niger, and Uganda. Accurate knowledge of the range of the four giraffe species should be used to guide such reintroductions, in order to support biodiversity goals and ensure appropriate and successful translocations and rewilding efforts (Brown et al. in press).

In some areas, giraffe occurrences are scarce or not recent; therefore, our estimated geographic ranges may be too large. For example, we have only limited knowledge of the precise ranges of giraffe in Ethiopia, Somalia, and South Sudan, where data can be hard to obtain due to political turmoil, instability, or lack of publicly accessible information (e.g. Wube et al. 2018). Similarly, in South Africa, where extralimital giraffe populations occur on private ranches, giraffe range data are not readily available (e.g. Fennessy et al. 2018a).

One challenge in delineating giraffe range is the lack of reliable information on species absence. Accurate absence data are rare and difficult to obtain, especially at regional scales (Jiménez-Valverde et al. 2007). Due to the current rate of human population increase and habitat fragmentation in much of Africa, some areas included in our range map may no longer support giraffe populations. This is especially true because we took a conservative approach to range reduction, only limiting areas for which we could confidently confirm, through expert knowledge of the area, that no giraffe are present. Therefore, increased surveys to improve knowledge of the distribution of giraffe throughout its range are necessary. Funding surveys to confirm presence and absence is difficult. Co-ordinating with other large mammal surveys occurring in areas of interest, such as was done here with the GEC, may be a plausible way to collect data on giraffe distribution.

The majority of our updates were based on aerial survey data, but some parts of the ranges where the habitat was unsuitable for aerial observation may need further refinement via ground surveys or other methods. For example, though data were contributed through the GEC, that project was originally designed for elephant detection and range coverage, not specifically for giraffe range and habitats (Chase et al. 2016). In addition, due to the detectability of giraffe, surveyors may have failed to observe all individual giraffe; small groups and lone individuals may have been especially prone to being missed. This may have resulted in an underestimate of giraffe geographic range (Lee & Bond 2016, Schlossberg et al. 2016). Aerial observations were used to

update the geographic range of giraffe in many areas, but ground observations could help confirm presence in additional areas. Alternatively, the reliability of aerial survey methods for giraffe monitoring could be examined and optimised, or new technologies that utilise photo-based methods from aircraft, unmanned aerial vehicles, or remote sensing from satellite with appropriate resolution could be explored (Linchant et al. 2015, Gonzalez et al. 2016). Additionally, despite our comprehensive literature and subject-matter expert search protocol, there may be relevant material unincorporated in this update that was not accessible through open source means or publically available from wildlife authorities and researchers.

As small giraffe populations can fluctuate rapidly (Shorrocks 2016) and the distribution of giraffe is patchy, range maps of these large mammals should be updated regularly to identify areas of high conservation priority (Chase et al. 2016, Ocampo-Peñuela et al. 2016, Morrison et al. 2018). This is especially important in the face of rapid and dynamic human infrastructure development that is taking place throughout Africa (Laurance et al. 2015). Appendix S6 shows the geographic range maps in relation to active and planned future major infrastructure developments that may affect giraffe ranges and habitat connectivity. Not much is known about the use of habitat corridors by giraffe, the effect of infrastructure development on giraffe populations, or how the new developments will affect giraffe populations specifically. Nevertheless, maps can be useful tools for communicating with policymakers and development planners, and for designing conservation efforts. Further resources and efforts should be employed in key areas throughout Africa, to conduct systematic giraffe surveys with harmonised protocols, in order to produce more precise range maps.

As land-cover and other remote sensing data increasingly become available, such data could be incorporated into range maps to assist in increasing map accuracy and in identifying highly important parts of the range for giraffe. It is also useful to identify parts of the range where giraffe are unlikely to occur, and to document the effects of fragmentation (Guisan et al. 2017). Incorporating such data may also help in determining absence, e.g. in urban areas that are no longer suitable habitat for giraffe.

Overall, this update not only improves our knowledge of the current geographical range of giraffe, but also highlights the need for further research and monitoring to inform effective conservation and management planning.

ACKNOWLEDGEMENTS

We express our sincere gratitude to the Great Elephant Census, Vulcan Inc., Kenya Wildlife Service, Grevy's Zebra Trust, Giraffe Conservation Foundation and Northern Rangelands Trust Wildlife-Conservancy Management Monitoring System, who helped provide the data for this update. We gratefully acknowledge the contributions of the Twiga Walinzi team of giraffe researchers in northern Kenya, whose vital giraffe research provided data for this update. In addition, we want to thank the following governments, organisations and individuals who have helped with this research: Governments and Wildlife Authorities of Botswana, Tanzania, Angola, Kenya, Cameroon, Ethiopia, Zimbabwe, and South Sudan, Loisaba Conservancy, Namunyak Conservancy, Lewa Conservancy, Northern Rangelands Trust, Sarara Camp, Mpala Research Centre, Bristol Zoological Society, Falk Grossmann, Soqui Mendiguetti, Paul Peter Awol, Orad Eldar, Blaise Mandaba, Ian Craig, Juliet King, Antony Wandera, Geoffrey Chege, Zeke Davidson, Cloe Pourchier, Osiris Doumbe, and the Robert Bosch Foundation, The Leiden Conservation Foundation.

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SUPPORTING INFORMATION AND DATA

Our giraffe geographic range shapefiles are available online at: https://drive.google.com/drive/folders/11jvtBaWohova0tFH1B1SPeAx3mO7GMVU?usp=sharing

Additional supporting information may be found in the online version of this article at the publisher's web-site.

Appendix S1. Summary of data used to update giraffe range maps.

Appendix S2. Full list of government-managed protected area (GMPA) designations.

Appendix S3. Giraffe distribution by country in sub-Saharan Africa.

Appendix S4. Specific changes and updates to the geographical distribution of giraffe as a result of this study.

Appendix S5. Updated geographical range of the giraffe, in comparison to the range in the 1700s.

Appendix S6. Updated geographical range of giraffe in relation to active and planned future major infrastructure development corridors in sub-Saharan Africa.