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**Key words:** insecurity, large herbivores, livestock, protected areas, tourism, trophy hunting.

**Abstract**: When in 2010 the world's governments pledged to increase protected area coverage to 17% of the world's land surface, several Central African countries had already set aside 25% of their land for conservation. To evaluate the effectiveness of this commitment, we analysed 68 multi-species counts conducted in the seven main savanna national parks in Central Africa (1960-2017). We also assembled information on potential drivers, and tourist numbers and revenues. The results show in six out of the seven parks a long-term decline of wild large herbivore populations, increase of livestock, and collapse of tourism, the pillar under a once thriving local wildlife industry. Zakouma NP (Chad) stands out by increasing large herbivore populations, positively correlated with the drivers rainfall and number of rangers, proxy for management inputs. With increasing insecurity and declining revenues, governments find themselves overstretched because the protected areas are too large and expensive to manage. To overcome this impasse, we propose to extend the presently proposed solutions – scaled up funding, enhanced management – with a strategic retreat, focusing scarce resources on smaller areas to save wildlife in the Central African savannas. It is our hope that from these well-managed and well-protected nuclei ultimately a viable conservation network can be rebuilt.

## Introduction

At the 2010 Convention on Biological Diversity summit, the world's governments agreed to expand protected areas to 17% of the world's land surface by 2020, that pending upcoming negotiations, may be raised to 30% by 2030. Although these percentages are considered too low by some (Wilson 2016), the annual costs of the 17% commitment are considerable, especially for low-income countries, and were estimated at US $76 billion (McCarthy et al. 2012). Since the 1970s, the Central African countries of Chad, Cameroon, Central African Republic (CAR) and Democratic Republic of Congo (DRC) have already set aside 25% of their northern savannas for conservation. The question that we examine here is whether this commitment of 245,000 $km^2$ of conservation areas – the size of the United Kingdom – has been effective in protecting wildlife in the savannas of Central Africa.

Over the last decade, the decline of large wild herbivore populations has been documented for protected areas across West, Central and East Africa (Caro & Scholte 2007; Scholte et al. 2007; Craigie et al. 2010; Ogutu et al. 2011; Bouche et al. 2012; Hillman Smith et al. 2015). The reasons behind these declines have seldom been explained, which hampers the development of effective conservation policies (Scholte 2011).

Here we set a next step, aiming to understand the observed trends in large herbivore populations and document related economic changes. We examine the long-term trends of large herbivore populations based on 68 aerial and terrestrial counts (1960 – 2017) in the seven main parks of the Central African savannas. We explore a set of potential drivers over this same time span that might help to explain the observed population trends (Scholte 2011). In addition, we examine changes in the numbers of tourists and tourist revenues. We expect that

parks showing negative conservation outcomes i.e., with declining wild herbivore populations, are confronted with reduced conservation inputs (budgets, rangers), increasing pressures (human and livestock numbers), and reduced socio-economic benefits (tourism) (Maxwell et al. 2020).

## Methods

### Study area

We concentrate on the Central African savannas as characterised by the East Sudanian savanna ecoregion, covering 1,06 million $km^2$, of which 25% has been conserved as national parks, game reserves, or low-intensity trophy hunting zones (Doumenge et al. 2015; Dinerstein et al. 2017). This ecoregion had an important local wildlife industry of photographic tourism and trophy hunting (Roulet 2004; Lescuyer et al. 2016), and comprises countries with comparable legal-political frameworks (Doumenge et al. 2015).

### Large herbivore surveys

We focus on large wild herbivores – elephant, giraffe, buffalo, and 10 antelope species – as indicators of conservation outcomes because of their (1) role as umbrella species for less known animals and plants, as reflected in the designation of six of the seven Central African national parks as Important Bird Areas (Fishpool & M.I. 2001; Macdonald et al. 2013); (2) economic value for tourism (Lescuyer et al. 2016); and (3) availability of long-term survey data (Scholte 2011). Large herbivores, detectable through direct observations in multi-species aerial and terrestrial surveys, have a weight of > 25 kg (e.g., red-fronted gazelle) in the open savanna

of Waza and Zakouma or > 50 kg (e.g., kob) in the wooded savannas of Bénoué, Bouba Ndjida CAR and Garamba (Jachmann 2002). The abundance of large herbivores was expressed as total metabolic biomass, based on species unit mass to the power 0.75 (kg), allowing for comparison across species, including livestock (Cumming & Cumming 2003).

Our analysis is based on data from the seven main savanna parks, selected on criteria of size (> 1700 $km^2$) and availability of at least four multispecies large herbivore surveys covering the past 3-5 decades. From the 68 aerial and terrestrial counts, 38 are sample counts of which 20 have information on confidence intervals, wheras the 30 total counts dominate the recent time-series bouts. Further details on survey methodology, and data sources on tourism and drivers are reported in Table S1 and Appendix S1.

**Data analysis**

To accommodate the heterogeneity of the 68 counts, we modelled the change of metabolic biomass of large wild herbivores over time with Generalized Additive Models (GAM) which have been used to analyse wildlife trends (Ogutu et al. 2011). We include year as a fixed factor with a negative binomial error distribution and log link function, and used a cubic B-spline covariance structure with a cubic difference penalty on the B-spline coefficients using 'gam' function in the 'mgcv' R package (Eilers & Marx 1996; Wood 2006). We assessed the approximate significance of smooth terms with Chi-square ($\chi^2$) and its estimated degree of freedom (est.df) (Wood 2006). Confidence intervals (CI) around predicted values (indicating uncertainty) increase steeply with long bouts between consecutive surveys. We therefore checked that significant trends with time were unequivocal by plotting fitted values (±CI).

The same procedure has been applied for the metabolic biomass of livestock, number of tourists, tourism taxes and revenues, and the number of rangers. Rainfall variation (i.e. the deviation of 5-year average annual value) with time was examined using Generalized Least-Squares (GLS) regression considering a first-order auto-regressive procedure with 'correlation=corAR1' and 'gls' function in the 'nlme' R package (Zuur et al. 2009). To test the effects of herbivore biomass of the potential drivers cited above, we used GLS regressions considering a first-order auto-regressive procedure. When data were not available from the same years, regressions were performed using predicted values from GAM and regression models described above. When possible, all independent variables were included in a comprehensive full model for the larger data sets. When co-linearity between independent variables occurred, drivers were tested separately.

## Results

Using data from 68 aerial and terrestrial counts in the ecoregion's seven main national parks, our analyses show overall a striking decline of large wild herbivores populations (Fig.1). Since the early 1980s, populations of wild large herbivores declined steadily in the three national parks in Cameroon ($\chi^2$>5.412, est. df>1.00, P<0.020) and especially in North CAR ($\chi^2$=218.60, est. df=3.05, P<0.001) and Garamba National Park, DRC ($\chi^2$=17.78, est. df=1, P<0.001). In contrast, in Zakouma National Park (Chad) wild large herbivore numbers have steadily increased since the mid-1980s ($\chi^2$=14.90, est. df=1.00, P<0.001).

Our analysis also shows that in the 1980s, pastoralists (from Chad and Sudan) moved into conservation areas of North CAR with their livestock ($\chi^2$=13.39, est. df=2.32, P=0.002). In

Cameroon, livestock movements into national parks and hunting zones is a more recent phenomenon ($\chi^2$>42.02, est. df>2.26, P<0.001). The decline in large herbivore populations generally started before the number of livestock increased in protected areas (Fig. 1).

There are several possible interrelated causes for the long-term decline of large herbivore populations in the Central African savannas, including rainfall variability, decreased numbers of park rangers, and low operational budgets. First, rainfall in the Central African savannas has on average decreased over the last decades (P<0.001). In two of the parks – Zakouma and Bouba Ndjida – the amount of rainfall is correlated with lower herbivore populations (respectively, β±SE=0.4±0.190, F=119.1, P<0.001; β±SE=11.4±3.1, F=13.5, P< 0.05). Second, the number of rangers has fluctuated over time ($\chi^2$>17.02, est. df>3.79, P<0.003). Only in Zakouma did the number of rangers increase ($\chi^2$=10.85, est. df=1.54, P=0.005) and here analyses show that when the number of park rangers increased, large herbivores populations increased as well (β±SE=1.3±0.2, F=45.5, P<0.001). Third, since the late 1980s the operational budget of Zakouma meets its financial needs, currently an annual US $800 $km^2$ (Lindsey et al. 2018; Scholte et al. 2018). Only more recently Garamba (> 2005) and Bouba Ndjida (>2016), have adequate budgets; these three parks represent only 10% of the Central African conservation area (Table S1).

The number of tourists ($\chi^2$>5.82, est. df>4.99, P<0.001) and trophy hunters ($\chi^2$>56.51, est. df>4.36, P<0.001), and the revenues they generate ($\chi^2$>25.9, est. df>1.91, P<0.001), have recently collapsed (Fig. 2). Reaching its peak in the mid-1980s, the number of tourists to the Cameroonian national parks has steadily declined and eventually collapsed with the Boko Haram attacks in Far North Cameroon that started in 2013. The numbers of trophy hunters in

Cameroon have remained remarkably stable, although hunting revenues have declined; while in the CAR, trophy hunting collapsed. Garamba has a history of small-scale tourism based on domesticated elephants, but this ended decades ago because of insecurity (Hillman Smith et al. 2015).

## Discussion

Until the early 2000s, large wild herbivore populations in the main protected areas of the Central African savannas declined less compared to large mammals in West Africa (Craigie et al. 2010; Scholte 2011). Underlying the dynamics of drivers differ. In Central Africa, rainfall rebounded following the 1970-80s droughts and human pressures have generally been lower and protected areas conserved with limited inputs and funding (Scholte 2011). Yet our study shows that large wild herbivore declines in the Central African savannas have accelerated over the past 10-20 years, now resembling the dramatic decline in West Africa (Craigie et al. 2010).

Here we review the explored drivers to build an understanding of the reasons behind the recently accelerated wildlife declines in the Central African savannas. Livestock now dominates all parks except Zakouma (Chad) and Garamba (DRC), the latter to the south of the pastoralists' range (Moritz et al. 2013). Our analysis indicates that pastoralists, reportedly driven by insecurity – Chad since 1979, Darfur since 2006, Boko Haram since 2010, and CAR since 2013 – have moved into parks that were earlier emptied of wildlife. However, the presence of livestock may now impede wildlife recovery through spatial interference or resource competition (Voeten & Prins 1999; Hibert et al. 2010). Rainfall – a driver of primary production – is correlated with large herbivore trends in the parks with medium and high wild

herbivores biomass i.e., Bouba Ndjida and Zakouma. We hypothesize that for the five parks with low wild herbivores' biomass, human influences obscure these natural processes. For example, Bénoué experienced a three-fold increase in human population due to immigration between 1998 and 2013, which was negatively correlated with large wild herbivore biomass (Scholte & de Groot 2010; Adam 2013). The number of rangers, a proxy for management inputs to tropical wildlife conservation (Bruner et al. 2001) is correlated with wild herbivore biomass in successful Zakouma, but fluctuates in the other parks. Zakouma stands out due to its long-term (>30 years) financial support from the European Union and its political commitment from the Chadian government (Scholte et al. 2018). In addition to these general drivers there are site and time specific drivers, such as upstream dam construction (1979) in Waza (Scholte et al. 2007) and massive elephant poaching in Zakouma (2006-8), an overspill from the conflict in neighbouring Darfur when conservation efforts were temporarily reduced (Poilecot 2010), Table 1. None of the explored drivers alone explain the declines. Our analysis hints at the existence of interactions between drivers, earlier observed in individual parks (Scholte et al. 2007). This interaction holds in particular for insecurity that impacts parks in the Central African savannas by triggering livestock movements into the last remaining wild places and ultimately inside the parks.

For decades tourism has been the pillar of a thriving local wildlife industry, attracting governmental investments (Roulet 2004; Lescuyer et al. 2016). The declining number of photographic tourists in Noth Cameroon runs in parallel with declining large wild herbivore population numbers, a relation sometimes reported as causal (Naidoo et al. 2016). Here we suggest an alternative explanation: reduced governmental investments in park management

and tourist infrastructures due to structural adjustment since 1990 (Tchoungui et al. 1995). The ailing photographic tourism crashed with the attacks of Boko Haram in Waza in 2013, also impacting the parks outside their direct influence (Pennaz et al. 2018). Trophy hunting seems to be more resilient to insecurity as shown in Cameroon; its collapse in the CAR a result from severe insecurity. In addition to insecurity, hunting enterprises, already barely profitable in 2012, are under pressure by a globally declining trophy hunting industry (Lescuyer et al. 2016; Lindsey et al. 2016). We conclude that not only has wildlife seriously declined, but also that the economic basis on which conservation has long relied, has almost disappeared.

These developments are in line with our initial expectations that park with declining wild herbivore populations are confronted with reduced conservation inputs, increasing threats and reduced socio-economic benefits. Moreover the case of Zakouma suggests that despite the threats of droughts and insecurity, wildlife and tourism may thrive in parks with long-term funding and political support. The success of Zakouma – which represents two percent of the Central African conservation area – notwithstanding, the message here conveyed is unmistaken and grave: declining large wild herbivore populations, massive intrusion of livestock, and collapse in tourism revenues, are the results of conservation overstretch in the Central African savannas in which conservation areas too large and expensive to manage.

**Saving wildlife in the Central African savannas**

Currently, conservation in the Central African savannas is at an impasse. To save the remaining wildlife, long-term funding needs to be increased by an order of magnitude (McCarthy et al. 2012; Lindsey et al. 2018), but insecurity in the region prevents this from happening. First,

tourists are unlikely to return because of the insecurity depriving protected areas from critical revenue sources, amplified by the COVID-19 crisis (Lindsey et al. 2020). Second, more external funding for the protected areas is not a realistic option because funders are reluctant to commit to long-term projects given the bleak security prospects of the region. Third, militarized conservation in high-risk regions negatively impacts neighboring communities and will damage the reputations of agencies and donors involved in these locations (Duffy et al. 2019).

Short-term financial injections are not a solution if it is not accompanied by structural changes to conservation practices. After the elephant slaughter in Bouba Ndjida in 2012, international donors raised a record amount of US $60 million. Yet, nine years later, the protection of Bouba Ndjida and neighbouring parks remains challenging (Fig. 1). Structural changes in conservation practices can involve the delegation of day-to-day park management to private partners with more technical and administrative capacities than governments. This delegated management has become common in the Central African savannas and includes Garamba (since 2005), Zakouma (2010), and North CAR (2018), (Scholte et al. 2018). Increasing funding and improving park management have been repeatedly promoted to stop the decline in wildlife (Bruner et al. 2001; McCarthy et al. 2012; Lindsey et al. 2018; Scholte et al. 2018; Maxwell et al. 2020). However, the absence of recovery of wildlife populations in Garamba (Fig. 1), as well as our experience in conservation in Central Africa over the last decades suggests that this will not be sufficient in the current insecurity context.

To save the remaining wildlife in Central Africa, it may be necessary to organize a strategic retreat, in which limited financial and human resources are focused on those areas with wildlife potential that are sufficiently large, 3000–4000 $km^2$ to support these wildlife

populations, and temporarily withdrawn from those areas that are currently protected in name only. This requires the commitment of governments, donors and conservation organization alike, to channel resources from orphaned parks to the parks with wildlife potential. The case of Zakouma – the only protected area in the Central Africa savanna where wildlife populations and tourism increased – suggests that long-term commitment and concentrating funding on a few parks is a viable option.

While downgrading and downsizing have been viewed as a threat to protected areas (Mascia et al. 2014), we argue that these methods can be used in situations of conservation overstretch. Our goal here is not to reject conservation ambitions – we share the concern that humankind is not doing enough to stop the loss of biodiversity. Instead we propose to extend the range of solutions – scaled up funding, improved management – with a strategic retreat, focusing scarce resources on areas where they will have the most impact to save wildlife in the Central African savannas.

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## Supporting Information

Appendix S1
Table S1

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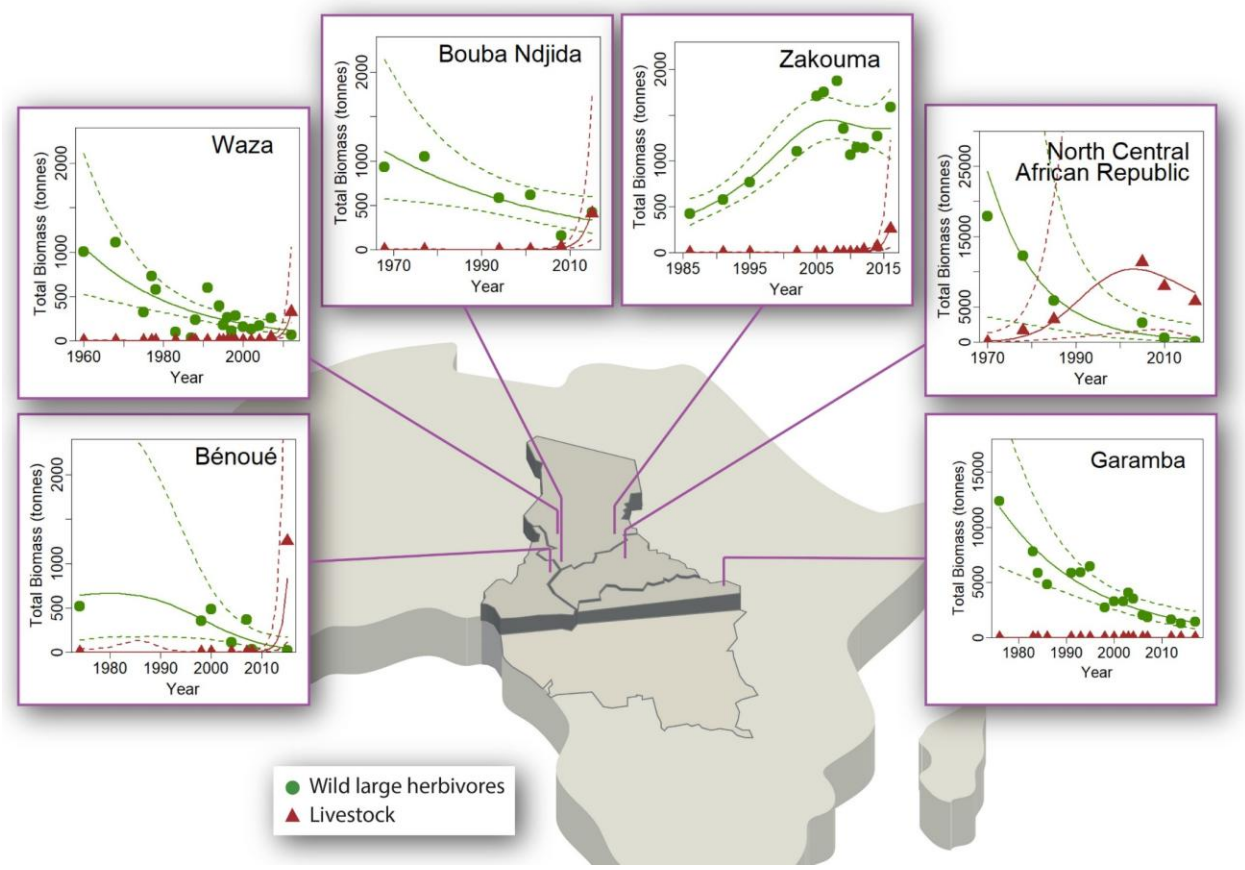
**Figure captions**

*Figure 1. Total biomass of large wild herbivores and livestock in national parks in the Central African savannas, 1960-2017.* Smoothed relationships between total metabolic biomass and time were obtained from nonparametric Generalized Additive Models. Model terms are presented as solid lines with dashed lines representing 95% confidence intervals. The North Central African Republic comprises Bamingui-Bangoran NP, Manovo-Gounda-St. Floris NP as well as adjacent trophy hunting zones.

*Figure 2. Numbers of tourists and revenues generated for protected areas in the Central African savannas, 1965-2018.* Smoothed relationships between the numbers of tourists (including trophy hunters) and revenues (including taxes) were obtained from nonparametric Generalized Additive Models. Model terms are presented as solid lines with dashed lines representing 95% confidence intervals.

## Figures

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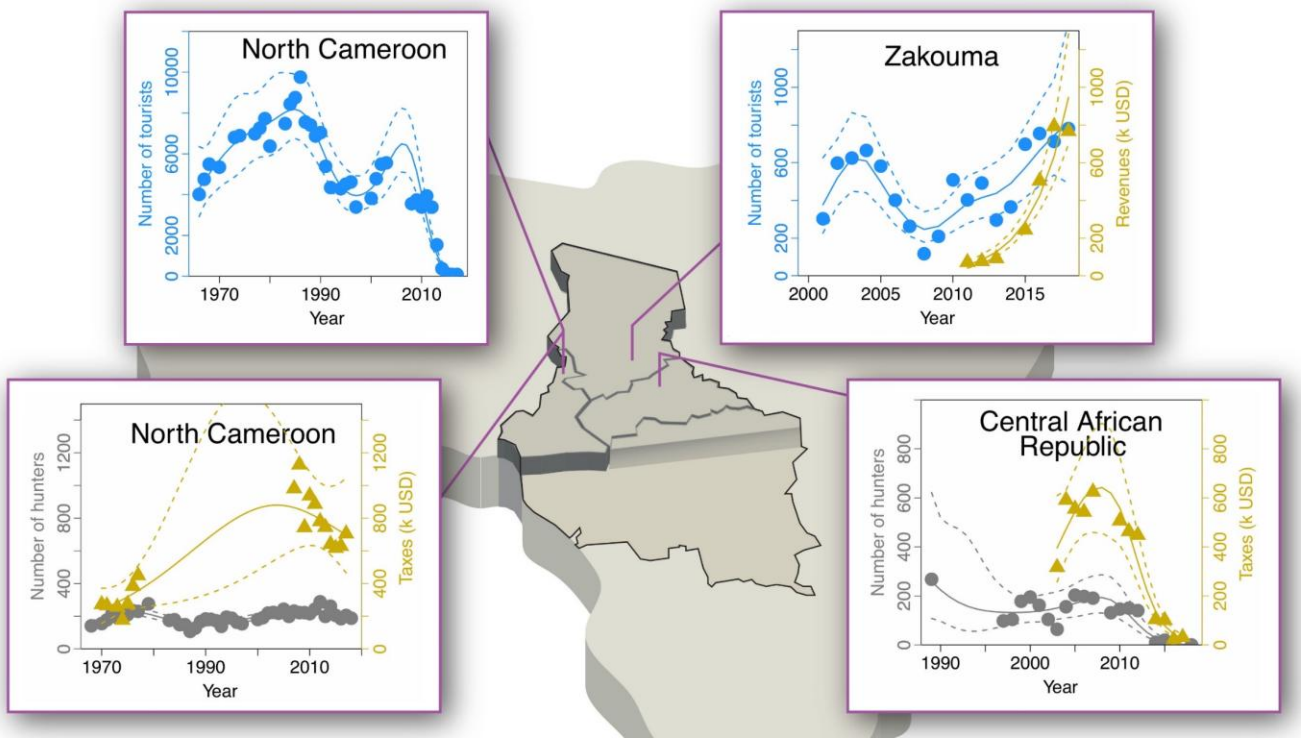


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