Climate change, disease range shifts, and the future of the Africa lion

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Running head: Disease range shift

Introduction

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Global climate change will shift disease patterns worldwide (Altizer et al. 2013). We explore how climate-induced changes to the geographic range of bovine trypanosomosis and its tsetse fly vector in Africa could dramatically alter the extent and frequency of interactions between domestic cattle and African lions (*Panthera leo*) – a species already in rapid decline (Riggio et al. 2013). Our findings suggest that these changes could negatively impact lions as a result of increasing cattle encroachment and escalating conflict between humans and lions.

In Africa, conflict is common between humans and lions. Habitat loss and wild prey depletion associated with livestock production, along with the retaliatory killing of lions in defense of humans and livestock are all leading causes of lion declines (Riggio et al. 2013). For example, in Kenya's Laikipia district, the number of lions that ranchers kill increases with the number of livestock that lions kill on their properties (Ogada et al. 2003). The pressure on African lion populations is likely to dramatically increase as the continent's human population and demand for livestock products are projected to double by 2050 (Rosegrant et al. 2009). Historically, in some regions, diseases suppress livestock production and so mitigate these pressures on lions.

An example is the tsetse-transmitted bovine trypanosomosis. Tsetse flies are hematophagous — they feed on blood — and can carry hemoparasites of genus *Trypanosoma.* Trypanosomosis occurs across approximately one-third of Africa's total land area. Of about 165 million cattle in Africa, 50 million are in tsetse-infested areas and are susceptible to trypanosomosis (Van den Bossche et al. 2010). The disease kills 3 million cattle annually in Africa at an economic loss of $1-1.2 billion (Ilemobade 2009). The impacts can be especially hard on smallholder cattle producers (Specht 2008). The parasite also affects humans, with 70,000 cases of 'sleeping sickness' per year and 60 million people at risk of infection in sub-Saharan Africa (Moore et al. 2012).

Although trypanosomosis harms cattle and humans, its suppression of cattle production limits conflict with large carnivores, such as lions. For example, in Mozambique's Niassa National Reserve, a lion stronghold of approximately 1,550 individuals (Riggio et al. 2013), cattle are absent due largely to the presence of trypanosomosis and lion-cattle conflict is non-existent (Jorge et al. 2013). Likewise, in the Luangwa Valley lion stronghold (~550 individuals) of Zambia, there are few livestock primarily because of the high trypanosomosis challenge and human-carnivore conflict is relatively uncommon (Riggio et al. 2013; Auty et al. 2016; Rosenblatt et al. 2016).

Climate-induced shifts in the geographic range of trypanosomosis

Temperature affects the development rate of the *Trypanosoma* parasites and can be one of the strongest abiotic determinants of distributions of its tsetse fly vectors (Rogers & Robinson 2004). We therefore examined areas (see methods in Supporting Information) in 12 countries in eastern Africa where the geographic range of a *Trypanosoma* parasite will likely shift by 2050 under two possible scenarios — Representative Concentration Pathways (RCP) 4.5 (moderate climate change mitigation) and 8.5 (business-as-usual) — thereby exposing hosts to different disease levels. Across the 12 countries in eastern Africa included in our analysis, the area over which the geographic range of the parasite is predicted to expand is greater than the area in which it is predicted to contract (Fig. 1). The extent of the parasite is forecast to expand by over 1,950,000 km^2 or 1,910,000 km^2 of new area by 2050 under RCP4.5 and RCP8.5, respectively (see Table S1 for results per country). That is, the disease may expand into about one-third of the region's total land area. In contrast, the parasite is predicted to disappear from about 520,000 km^2 (RCP4.5) or 714,000 km^2 (RCP8.5) by 2050, amounting to 9% or 12%, respectively, of the region's total land area. Net changes amount to a 25% or 21% increase in the geographic range of the parasite for RCP4.5 and RCP8.5, respectively. Range changes vary considerably by country. For example, using results from RCP8.5, the parasite will disappear from over 43% of Mozambique's land area and expand into 20%, while the parasite will disappear from 22% of Tanzania's land area and expand into 17%.

Implications of trypanosomosis range shifts on lions

We predict the parasite will disappear by 2050 from approximately 19% (RCP4.5) or 28% (RCP8.5) of the total area encompassed by the 38 lion areas (i.e., places that likely have resident lion populations as calculated in Riggio et al. 2013) in eastern Africa. We predict about one-third of these existing areas (11/38 for RCP4.5 and 15/38 for RCP8.5) will experience a net contraction in the geographic range of the parasite, potentially releasing cattle from disease control and increasing lion-cattle interactions (see Tables S2, S3 and Fig. 2 for results per lion area, and Tables S4, S5 for results using alternative *Morsitans* presence threshold values). Moreover, 27% (3/11) for RCP4.5 or 45% (5/11) for RCP8.5 of potential or known lion strongholds (areas supporting >500 lions) are predicted to experience a range contraction in the parasite. For example, using RCP8.5 projections, the parasite will disappear from 18% of Luangwa, 4% of Mid-Zambezi, 48% of Niassa, 10% of Ruaha-Rungwa, and 61% of Selous (Fig. 2).

Conversely, nearly 70% (26/38 for RCP4.5) or 60% (22/38 for RCP8.5) of lion areas are expected to see a range expansion in the parasite and subsequent suppression of livestock production. For example, using RCP8.5 projections, the parasite may expand into portions of six potential or known lion strongholds, including 35% of Kafue, 39% of Great Limpopo, 44% of Laikipia-Samburu, 11% of Serengeti-Mara, 49% of Tarangire, and 42% of Tsavo-Mkomazi.

Assuming lions are uniformly distributed across lion areas, the predicted disappearance of the parasite by 2050 could affect 3,900 (RCP4.5) or 6,500 (RCP8.5) lions — 11% or 19%, respectively, of the total lion numbers in Africa (Tables S2, S3, Fig. 2, Riggio et al. 2013). Of those lions potentially exposed to greater interactions with cattle, 3,400 (RCP4.5) or 5,900 (RCP8.5) reside in lion strongholds.

Long-term lion conservation – are we prepared?

Cattle are major drivers of economic and ecological changes worldwide (Herrero et al. 2009). The growth in cattle numbers where they previously had been sparse can have complex effects on carnivore populations. Increased cattle presence can reduce wild prey species, aggravate carnivore-cattle conflict, promote human killing of carnivores in response to cattle depredation, and simplify landscapes through ecosystem degradation and fragmentation (Green et al. 2017; Reid et al. 2009). On the other hand, a consistent source of protein and income from domestic livestock might reduce illegal bushmeat hunting, which is a major threat to carnivores and their prey (Wilkie et al. 2016). Assessing these tradeoffs in the diverse social, political, and cultural contexts across the continent where lion habitat and cattle production currently co-occur or may interface in the future merits further investigation.

Climate-induced range shifts in tsetse flies, coupled with efforts to eradicate or control trypanosomosis and improve public health and livestock production (Diall et al. 2017), will continue to alter the extent and magnitude of lion interactions with cattle and herders in the future. Land managers should consider interventions to mitigate increasing interactions between lions and cattle (e.g., reinforced bomas) in regions where cattle production might increase due to decreased suppression by bovine trypanosomosis. For example, rangeland-management approaches, such as mixed revenue streams and facilitated grazing, can be used to offset the costs of livestock depredation by lions and justify their protection on shared landscapes outside protected areas (Toit et al. 2017). Grazing allotments for intensive cattle production, however, should be positioned to reduce impacts on protected areas and not encroach in to buffer zones that sustain core lion habitats. Conservation incentives, such as biodiversity payments and conservation easements, collaborative management and local conservancies, and public-private investment partnerships, can secure buffer-zones and corridors around protected areas, and promote compliance (Reid et al. 2009). One such example is Mozambique’s Gorongosa Ecosystem, where efforts are underway to recover the lion population, design wildlife corridors, and implement community-led conservancies within a matrix of changing land-use that includes increasing cattle production. Growing numbers of small-scale cattle operations in Gorongosa could be a consequence of reduced bovine trypanosomosis prevalence already being caused by climate-induced range shifts in the parasite (see Table S2, S3).

We need a greater understanding of the causes and consequences of range shifts in bovine trypanosomosis (and other diseases) in order to direct conservation resources to mitigate the negative effects of these shifts on lions and other wildlife. Such knowledge can be integrated into the IUCN-led, region-wide management strategies for the African lion that are currently being formulated and implemented by nations managing extant lion populations across Africa. Without proactive, long-term planning that integrates predicted shifts in disease impacts, the lion conservation community remains unprepared for future climate-induced challenges.

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Figure Captions

Figure 1. Map of 12 countries in eastern Africa showing predicted shifts in the geographic range of *T. b. rhodesiense* by 2050 based on temperature changes for climate scenarios RCP4.5 (moderate climate change mitigation) and RCP8.5 (business-as-usual). Details on methodology can be found in Moore et al. 2012 and supporting text S1. Note that the model excludes some parasites and vectors more prevalent in other regions of Africa with important lion areas, such as West Africa.

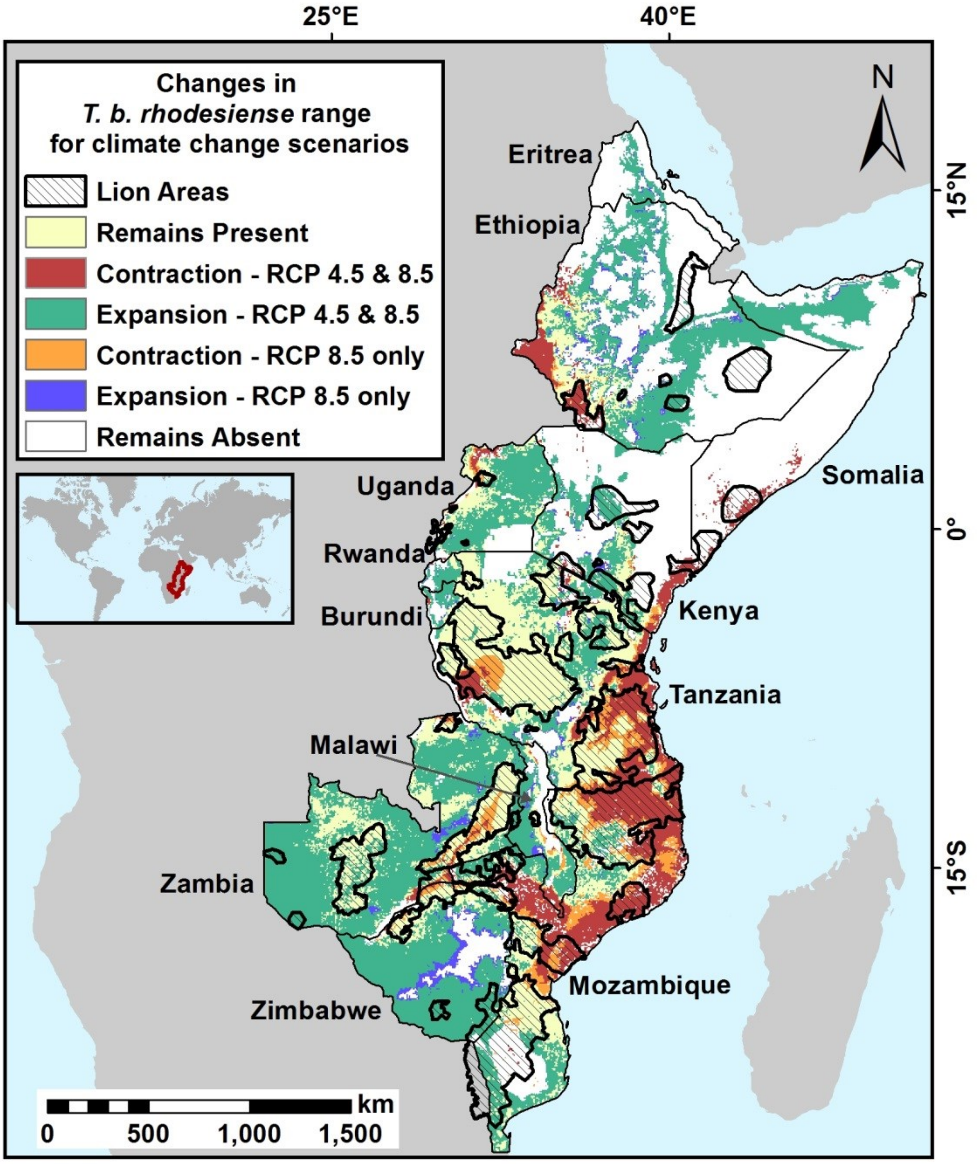
25°E
40°E
15°N
0°
15°S
Changes in
T. b. rhodesiense range
for climate change scenarios
Lion Areas
Remains Present
Contraction - RCP 4.5 & 8.5
Expansion - RCP 4.5 & 8.5
Contraction - RCP 8.5 only
Expansion - RCP 8.5 only
Remains Absent
N
Eritrea
Ethiopia
Somalia
Uganda
Rwanda
Burundi
Kenya
Tanzania
Malawi
Zambia
Mozambique
Zimbabwe
0 500 1,000 1,500 km

Figure 2. Lion areas (15) in eastern Africa predicted to experience a net contraction in the geographic range of *T. b. rhodesiense* by 2050 based on temperature changes for climate scenario RCP8.5 (business-as-usual). Lion strongholds (5) are outlined in black. Y-axis on the left shows the percentage of each lion area predicted to experience a reduction in the parasite's geographic range, thereby releasing cattle in the area from control by trypanosomosis. Based on those percentages, the Y-axis on the right shows the number of lions ($\log_{10}$ transformed) that could consequently experience greater interactions with cattle, assuming a uniform distribution of lions in the lion areas using lion numbers from Riggio et al. 2013.