Fiddling in biodiversity hotspots while deserts burn? Collapse of the Sahara's megafauna

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Abstract:

A catastrophic decline in megafauna biodiversity in the world's largest tropical desert, the Sahara, has occurred while conservation attention has been focused elsewhere. Of 14 large vertebrates that have historically occurred in the region, four are now extinct in the wild, including the iconic scimitar-horned oryx. Moreover, the majority has disappeared from more than 90% of their range, including addax, dama gazelle and Saharan cheetah - which are now on the brink of extinction. Greater conservation support and scientific attention for the region might have averted these catastrophic declines. The Sahara serves as an example of a wider historical neglect of deserts and the human communities who depend on them. The scientific community can make an important contribution to Saharan conservation by establishing baseline information on biodiversity and developing new approaches to sustainable management of desert biodiversity and ecosystems that allow for their high variability in rainfall patterns. This will be needed to enable governments to deliver on their commitments to halt further degradation of desert ecosystems, and to improve their status for both biodiversity conservation and human well-being. Only by so-doing will deserts be able to support resilient ecosystems and communities who are best able to adapt to climate change.

The importance of desert ecosystems

Global biodiversity is being lost at rates that are unprecedented. Vertebrate species are declining at rates 100-1000 times higher than those in evolutionary history (Dirzo & Raven, 2003; Mace *et al.*, 2005), and climate change is projected to increase extinction rates further (Thomas *et al.*, 2004). Conservation biologists have argued convincingly that targeting funding at tropical forests and other "biodiversity hotspots" maximises the number of species conserved per conservation dollar (Kerr, 1997; Mittermeier *et al.*, 1998; Reid, 1998; Myers *et al.*, 2000; Brooks *et al.*, 2002; Sechrest *et al.*, 2002). Concerns about climate change have further focused attention on forests, because forest degradation and loss are responsible for a significant proportion of anthropogenic greenhouse gas emissions, while maintaining forest cover is a potentially cost-effective mechanism for both climate change mitigation and adaptation (Denman *et al.*, 2007).

However, prioritisation of forests and biodiversity hotspots for conservation has inevitably resulted in the neglect of important biodiversity in other biomes (Grenyer *et al.*, 2006). In particular, desert biodiversity has attracted relatively little conservation finance and action (Davies *et al.*, 2012; Durant *et al.*, 2012), although deserts cover 17% of the world's land mass and harbour surprisingly high biodiversity (Safriel *et al.*, 2005), despite their low primary productivity and consequent low biomass. In fact, the vast scale of desert ecosystems results in relatively similar overall biodiversity to forests at the biome level, despite the latter's extremely high biodiversity at smaller scales. For example, deserts are home to 25% of terrestrial vertebrate species and, combined with xeric shrublands, are among the top three richest biomes for terrestrial vertebrates (Mace *et al.*, 2005; Millenium Ecosystem Assessment, 2005). Desert biodiversity can yield important insights into the physiological and genetic basis of species tolerance to water stress and extreme temperatures. Such knowledge can improve dryland agricultural practices and conservation management, and is especially critical in a changing climate (Merkt & Taylor, 1994; Mueller & Diamond, 2001; Darkoh, 2003).

Desert and other dryland ecosystems also provide vital resources for human communities. Six percent of the world's human population inhabit deserts (Mortimore *et al.*, 2009), including some of 'the poorest, the hungriest, the least healthy and most marginalized people in the world' (Middleton *et al.*, 2011). Human desert communities inhabit an exceptionally harsh and variable environment and are especially vulnerable to the impacts of ecosystem degradation and the disruption of critical ecosystem services (Mortimore *et al.*, 2009). Desert peoples and ecosystems are likely to confront even greater challenges in the near future, because the rate of climate change is projected to be particularly high in the desert biome (Loarie *et al.*, 2009). Yet deserts also have substantial potential to contribute to climate regulation. The vast extent of deserts and other dryland ecosystems harbour an estimated one-third of terrestrial global carbon stock (Trumper *et al.*, 2008), with further potential for carbon sequestration through improved land management (Keller & Goldstein, 1998; Lal, 2001).

The Sahara – a forgotten desert

Desert ecosystems have received disproportionately little scientific attention compared with other biomes. Between 2000-2012 the majority of scientific publications in ecology focused on the forest biome (67%) and only a minority on deserts (9%) (Durant *et al.*, 2012; ISI Web of Science search, 2012). The Sahara, the world's largest desert, covering 40% of the Africa continent, harbours iconic large mammal biodiversity, yet has attracted very little scientific attention. Between 2000-2012 only 32 ISI ecology papers were focused on studies of Saharan biodiversity, with little sign of an increase in coverage over recent years, despite an overall increase in publications in ecology (over the same period ecology publications under forests increased by 84%).

The lack of scientific attention given to desert biodiversity is mirrored by a lack of financial support. Although the Sahara covers 40% of Africa's land mass, only 12% of Global Environment Facility funding to Africa went to Saharan nations between 1991-2009 (Global Environmental Facility, 2010; Durant *et al.*, 2012). Similarly, only 1% of funds provided by the UK's Darwin Initiative between 1992-2008 went to projects in desert biomes, compared with 23% to forests over the same period (www.defra.darwin.gov.uk; Hardcastle, 2008; Durant *et al.*, 2012). Large mammals have disappeared from desert landscapes largely unobserved and unremarked within the conservation community.

Two workshops organised by the Zoological Society of London and the Wildlife Conservation Society in 2010 and 2012? focused on the Sahel-Sahara have shed a long overdue light on the status on large mammal biodiversity in this region. These workshops used an expert-based process (Sanderson *et al.*, 2002; IUCN/SSC, 2007a, b, 2012) to establish current areas of known resident range for 14 species and subspecies of large vertebrate found in the Sahel-Sahara region. These taxa include all of the large herbivores and all but one of the large carnivores found in the region, and their presence is indicative of effective ecosystem function and management. The single species not included in the analysis was the striped hyaena (*Hyaena hyaena*), for which there is little distributional data.

In the workshop process species experts and protected area managers agreed on the boundaries of historical and resident range for each species.   Of the 14 species assessed, 10 (71%) are endemic to the Sahel-Sahara region, and 12 (86%) are considered by the IUCN Red

List to be either extinct in the wild or globally threatened with extinction (Table 1). The maps (Fig 1?) clearly show a massive collapse in large vertebrate distributions across the region. Thirteen of the 14 species have disappeared from 79% or more of their historical range, and nine species have disappeared from 90% or more of their range (Table 1, Fig 1). Shockingly 50% of the 14 species are either extinct or confined to 1% or less of their historical range. The range collapse of the species still extant raises concerns for their future survival; only the Barbary sheep (*Ammotragus lervia*) and the dorcas gazelle (*Gazella dorcas*) are relatively secure (in that the still show relatively large ranges?).

The collapse of this iconic desert fauna is particularly alarming because the habitat is still largely intact. Past and ongoing insecurity across the region, and consequent difficulties in access for conservationists and other key actors, have undoubtedly contributed to these declines (Brito *et al.*, 2013), however it is difficult to escape the conclusion that lack of financial support and scientific attention may have also played a role. Despite this, there have been some success stories. Niger is to be congratulated on its recent gazettement of the 97,000km^2 Réserve Naturelle Nationale de Termit et du Tin Toumma, which harbours around 150 of the world's remaining 200 Critically Endangered addax (*Addax nasomaculatus*). Chad also deserves support for its program to bring back scimitar-horned oryx (*Oryx dammah*) to Ouadi-Rime reserve, a species currently Extinct in the Wild (Bemadjim *et al.*, 2012). These successes are partly a result of support from the Convention on Migratory Species (CMS) (UNEP/CMS, 1999, 2006), which has stimulated a wide range of important conservation efforts in the region. However, countries such as Niger and Chad require additional support if they are to safeguard biodiversity effectively across such enormous landscapes. This can only be obtained if the conservation community increases its focus on biodiversity in hitherto neglected ecosystems.

Restoring the empty desert

The world will be a poorer place if the unique biodiversity of deserts such as the Sahara is allowed to disappear. Given low human densities and that over 90% of tropical arid and hyper-arid lands remain uncultivated (Mortimore *et al.*, 2009), management of natural resources in desert ecosystems may actually be substantially cheaper than maintaining or restoring tropical forest habitats. Although there is no comprehensive analysis of the causes and patterns of biodiversity loss in deserts, species threat status appears to be related to body size, suggesting key pressures are likely to be habitat loss or degradation and hunting or persecution by humans (Safriel *et al.*, 2005).

There is increasing evidence of a need for a paradigm shift in approach for biodiversity conservation and human development in desert systems. Wildlife living in deserts are nomadic and wide ranging – able to respond quickly to sporadic rainfall events, and take advantage of the nutrients provided by fresh growth. Nomadic pastoral people living in deserts, mimic the mobility adaptations of the wildlife with which they share their land, enabling them also to take advantage of variable rainfall and monopolise grazing resources at the peak of their productivity. Unfortunately, however, there is increasing pressure to settle people, as governments push to increase agriculture in deserts in the mistaken belief that this is the route to food security. Such changes in land use in unpredictable low rainfall environments have led to widespread desertification, and increased vulnerability for the people and their livestock who inhabit these systems. Accepting that mobility of both people and wildlife is key to efficient use of dryland resources is an essential precursor to the sustainable management of desert ecosystems (IIED, 2013).

Developing a better understanding of sustainable management of desert ecosystems is increasingly urgent as we approach an era where climate change is expected to increase drought in many regions of the globe. While clearly biodiversity hotspots are important and deserving of world attention, the velocity of climate change in desert biomes is predicted to be among the fastest, while that in tropical forests would be? relatively low (Loarie *et al.*, 2009). Adaptation to minimize the impacts of climate change in deserts is thus likely to be particularly challenging. If the neglect of desert biodiversity continues then there is a real risk that much of their unique flora and fauna will be lost, and, along with it, some of the key information and tools for adaptation to a warming planet.

We are now in the fourth year of the United Nations Decade for Deserts and the Fight against Desertification and the third year of the United Nations Decade for Biodiversity. This is an opportune decade for the world's attention to focus on securing the sustainable management of desert ecosystems. Such approaches need to take into account the extreme variability in desert systems, and enshrine the need for mobility for both people and wildlife. This will benefit both biodiversity and some of the world's most impoverished and marginalized human communities, while also helping to mitigate against global climate change.

Governments are committed to meet the minimum target of a zero net rate of land degradation as agreed at Rio +20 in the UN Convention on Sustainable Development (UNCSD, 2012). If this goal is to be achieved it will require the full engagement of the scientific community. We urge scientists and conservationists to prioritise applied research into the conservation of biodiversity and the restoration of ecosystem function in deserts, including restocking of wildlife/wild species, so that these can once more support their full complement of species and provide increased resilience for local human communities. There is an urgent need for baseline information on biodiversity trends and threats to desert ecosystems, and research and development of locally appropriate strategies and tools to strengthen conservation management (Davies *et al.*, 2012). This will require sustained financial support and capacity development within desert range states. However, over the medium to long-term, such investment is likely to be more cost-effective than trying to address and reverse the ecological and socio-economic impacts of biodiversity loss and ecosystem service degradation in a changing climate.

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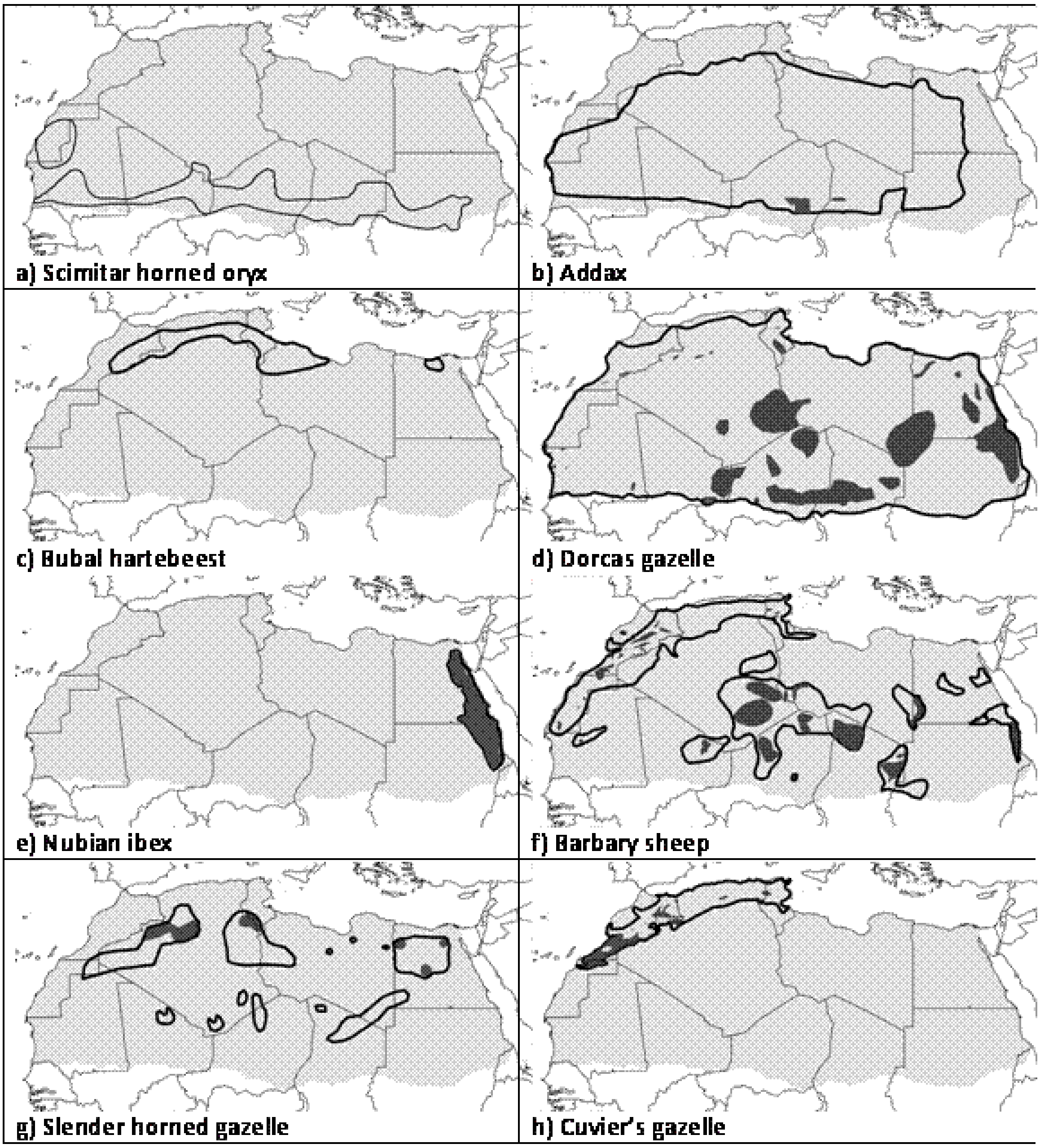
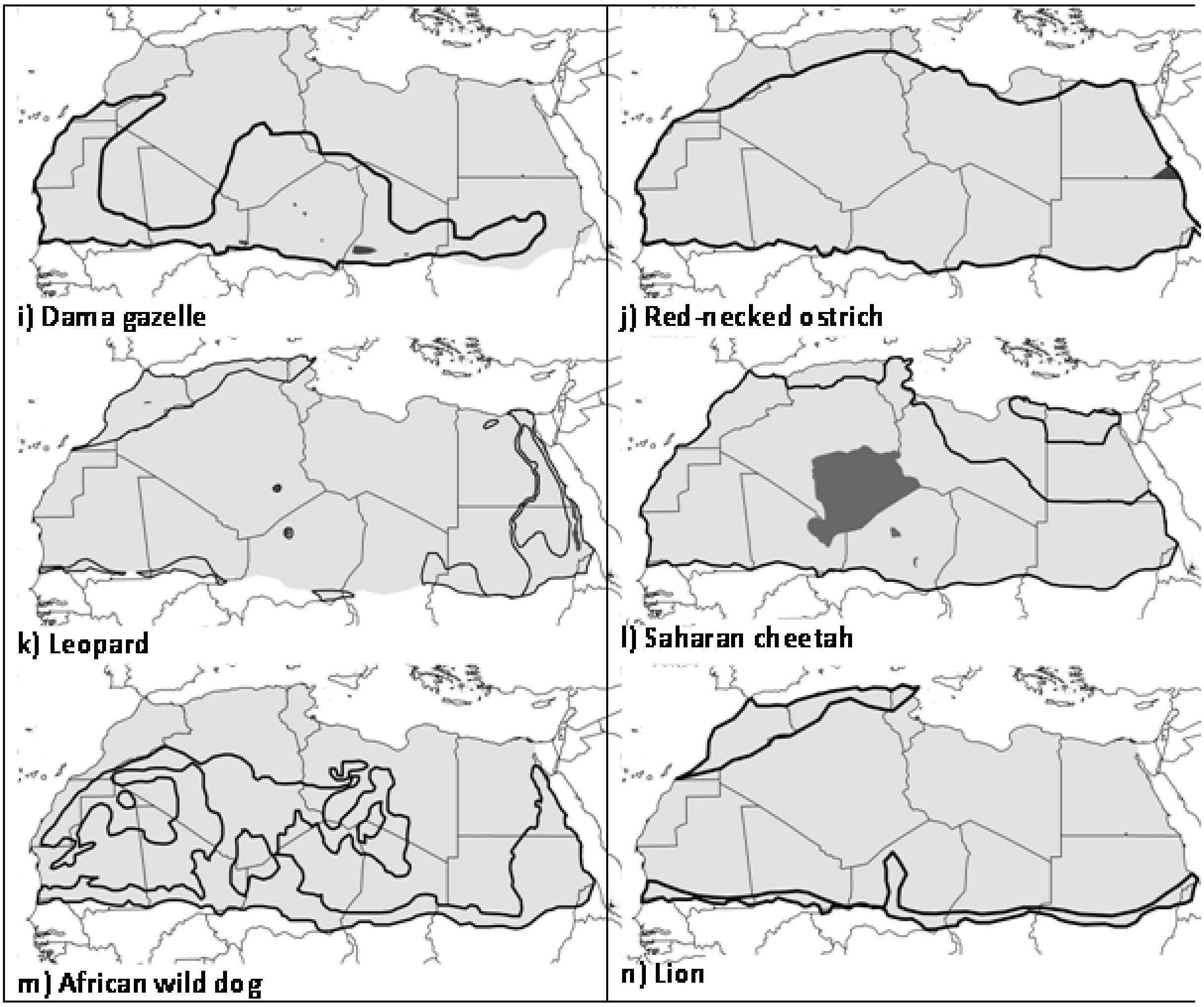
Table 1 Percentage of loss of range compared to estimated historical range for 14 of 15 species of large vertebrate in the Sahelo-Saharan region (excluding striped hyaena – for which there was insufficient information). See Fig. 1 legend for more details on mapping process.

Species	Scientific name	IUCN Red List status	Historical range (km^2)	Current known resident range (km^2)	% range loss
Scimitar horned oryx	*Oryx dammah*	Extinct in the Wild	1,545,360	0	100
Addax	*Addax nasomaculatus*	Critically Endangered	6,911,931	47,155	99
Bubal hartebeest	*Alcelaphus buselaphus buselaphus*	Extinct	634,863	0	100
Dorcas gazelle	*Gazella dorcas*	Vulnerable	10,136,683	1,359,369	87
Nubian ibex	*Capra nubiana*	Vulnerable	320,636	287,902	10
Barbary sheep	*Ammotragus lervia*	Vulnerable	2,722,315	564,860	79
Slender horned gazelle	*Gazella leptoceros*	Endangered	1,299,773	182,005	86
Cuvier's gazelle	*Gazella cuvieri*	Endangered	699,478	137,730	80
Dama gazelle	*Nanger dama*	Critically Endangered	3,632,827	23,222	99
Red-necked ostrich	*Struthio camelus camelus*	Least Concern†	9,487,855	18,719	99.8
Leopard	*Panthera pardus*	Near Threatened	1,386,517	30,454	98
Saharan cheetah	*Acinonyx jubatus hecki*	Critically Endangered	8,745,627	813,947	91
African wild dog	*Lycaon pictus*	Endangered	3,756,634	0	100
Lion	*Panthera leo*	Vulnerable	1,240,829	0	100

†Saharan race morphologically and genetically distinct but Red List status not yet assessed

Fig 1 Maps of range loss for 14 species in the Sahelo-Saharan region (grey shading). The region was defined as land where annual rainfall was below the 200mm isohyet. Ranges were mapped by species experts using a widely used expert based process, adapted from that developed by WCS (Sanderson *et al.*, 2002; IUCN, 2006; IUCN/SSC, 2007a, b). Historical range (thick black line) refers to land formerly occupied by the species prior to major anthropogenic change. Resident range (black shading) refers to land known to support resident populations of a species within the last 10 years. Note that resident range covers areas where species are known to occur. There are areas outside this range where species may still occur, but where information is lacking, however the extent of this range is not expected to significantly change the range loss estimates in Table 1. Note also that we have not depicted resident or historical range outside the Sahelo-Saharan region, although not all species are endemic to the region. Small fenced reserves where populations are not self sustaining are not depicted on these maps.




i) Dama gazelle
j) Red-necked ostrich
k) Leopard
l) Saharan cheetah
m) African wild dog
n) Lion