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BIODIVERSITY VIEWPOINT

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

S. M. Durant[1,2]*, T. Wacher[3], S. Bashir[4], R. Woodroffe[1], P. De Ornellas[3], C. Ransom[3], J. Newby[5], T. Abáigar[6], M. Abdelgadir[7], H. El Alqamy[8], J. Baillie[3], M. Beddiaf[9], F. Belbachir[1,10], A. Belbachir-Bazi[10], A. A. Berbash[11], N. E. Bemadjim[12], R. Beudels-Jamar[13], L. Boitani[14], C. Breitenmoser[15], M. Cano[6], P. Chardonnet[16], B. Collen[17], W. A. Cornforth[1], F. Cuzin[18], P. Gerngross[19], B. Haddane[20], M. Hadjeloum[21], A. Jacobson[1], A. Jebali[22], F. Lamarque[23], D. Mallon[24], K. Minkowski[25], S. Monfort[26], B. Ndoassal[12], B. Niagate[27], G. Purchase[2,3], S. Samaïla[28], A. K. Samna[28], C. Sillero-Zubiri[29], A. E. Soultan[30], M. R. Stanley Price[29,31] and N. Pettorelli[1]

[1]Institute of Zoology, Zoological Society of London, Regents Park, London NW1 4RY, UK, [2]Wildlife Conservation Society, Bronx Zoo, 2300 Southern Blvd., Bronx NY 10460, USA, [3]Conservation Programmes, Zoological Society of London, London NW1 4RY, UK, [4]Birdlife International Asia, 247672, Singapore, [5]Sahara Conservation Fund, 1148, L'Isle Switzerland, [6]Estación Experimental de Zonas Áridas (EEZA), CSIC, Carretera de Sacramento s/n, Almería Spain, [7]Department of Biology, University of Hail, Hail Saudi Arabia, [8]Egyptian Environmental Affairs Agency (EEAA), Cairo Egypt, [9]Office National du Parc Culturel du Tassili n'Ajjer, Djanet 33100, Algeria, [10]Laboratoire d'Ecologie et Environnement, Faculté des Sciences de la Nature et de la Vie, Université de Béjaïa, 06000, Béjaïa Algeria, [11]Nature Conservation Department, Environment General Authority (EGA), Tripoli Libya, [12]Direction des Parcs Nationaux des Réserves de Faune et de la Chasse, N'Djamena Tchad, [13]Royal Belgian Institute of Natural Sciences, 1000, Bruxelles Belgium, [14]Department Biology & Biotechnologies, Università La Sapienza, Viale Università 32, 00185, Rome Italy, [15]Co-Chair IUCN/SSC Cat Specialist Group, 3074, Muri Bern Switzerland, [16]La Fondation Internationale pour la Gestion de la Faune 75003, Paris France, [17]Centre for Biodiversity & Environment Research, University College London, London WC1E 6BT, UK, [18]BP 1172

ABSTRACT

Biodiversity hotspots understandably attract considerable conservation attention. However, deserts are rarely viewed as conservation priority areas, due to their relatively low productivity, yet these systems are home to unique species, adapted to harsh and highly variable environments. While global attention has been focused on hotspots, the world's largest tropical desert, the Sahara, has suffered a catastrophic decline in megafauna. Of 14 large vertebrates that have historically occurred in the region, four are now extinct in the wild, including the iconic scimitar-horned oryx (*Oryx dammah*). The majority has disappeared from more than 90% of their Saharan range, including addax (*Addax nasomaculatus*), dama gazelle (*Nanger dama*) and Saharan cheetah (*Acinonyx jubatus hecki*) – all now on the brink of extinction. Greater conservation support and scientific attention for the region might have helped to avert 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 conservation in deserts by establishing baseline information on biodiversity and developing new approaches to sustainable management of desert species and ecosystems. Such approaches must accommodate mobility of both people and wildlife so that they can use resources most efficiently in the face of low and unpredictable rainfall. This is needed to enable governments to deliver on their commitments to halt further degradation of deserts 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 that are best able to adapt to climate change.

Keywords
Drylands, large carnivores, mammal distribution, ostrich, UNCCD, ungulates.

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Bab Agnaw, 40000, Marrakech Morocco, [19]BIOGEOMAPS, Umwelt-PR Gerngross e.U., A-1070, Vienna Austria, [20]Fondation Mohamed VI pour la Protection de l'Environnement-Rabat Maroc/Programme Biodiversity, Rabat Morroco, [21]Direction Générale des Forêts, Direction de la Protection de la Faune et de la Flore, Chef de Bureau de la Gestion et de la Préservation de la Faune, Algiers Algeria, [22]Tunisia Wildlife Conservation Society (TWCS), Département de Biologie, Faculté des Sciences de Tunis, Campus Universitaire, 2092, Tunis Tunisia, [23]Ministère de l'Ecologie, du Développement Durable et de l'Energie – Sous-direction de la protection et de la valorisation des espèces et de leur milieu, 92055, La Défense CEDEX France, [24]Division of Biology and Conservation Ecology, Manchester Metropolitan University, Manchester M1 5GD, UK, [25]2395 Delaware Ave., #66 Santa Cruz CA, 95060, USA, [26]Smithsonian Conservation Biology Institute, National Zoological Park, Front Royal VA, USA, [27]Directeur du Parc National et Réserve de Biosphère de la Boucle du Baoulé, BP 275, Bamako Mali, [28]Direction de la Faune, de la Chasse et des Aires Protégée, BP 578, Niamey Niger, [29]Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, The Recanati-Kaplan Centre, Tubney OX13 5QL, UK, [30]St Katherine Protectorate, Nature Conservation Sector, Egyptian Environmental Affairs Agency (EEAA), Cairo Egypt, [31]Al Ain Zoo, Abu Dhabi Saudi Arabia

*Correpondence: S. M. Durant, Institute of Zoology, Zoological Society of London, Regents Park, London NW1 4RY, UK.
E-mail: s.durant@ucl.ac.uk

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; Foden *et al.*, 2013). Conservation biologists have argued convincingly that targeting funding at tropical forests and other 'biodiversity hotspots' maximizes 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 is responsible for a significant proportion of anthropogenic greenhouse gas emissions; hence, maintaining forest cover is a potentially cost-effective mechanism for climate change mitigation (Denman *et al.*, 2007; Nabuurs *et al.*, 2007).

However, prioritization 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 may even be relevant to human health; information that is critical to adaptation to a changing climate (Merkt & Taylor, 1994; Mueller & Diamond, 2001; Darkoh, 2003).

Desert and other dryland ecosystems also provide vital resources for human communities. Six per cent 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 unpredictable environment and are especially vulnerable to the impacts of ecosystem degradation and the disruption of critical ecosystem services (Mortimore *et al.*, 2009). However, as with desert biodiversity, the plight of desert-dwelling people has gained little global attention. The UN Convention to Combat Desertification (UNCCD), a convention specifically designed to address the needs of such communities, remains one of the weakest of the UN conventions (Conliffe, 2011). Lack of funding and political will have meant that progress towards the UNCCD's goal of reversing land degradation and desertification has been elusive (Tollefson & Gilbert, 2012). Meanwhile the people living in these environments continue to be perceived as peripheral and unimportant and are neglected by political and business communities (Middleton *et al.*, 2011).

Desert peoples and ecosystems are likely to face 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 not only been neglected by the conservation and development communities, but they have also received disproportionately little scientific attention compared with other biomes. Between 2000 and 2011, the majority of scientific publications in ecology focused on the forest biome (67%) and only a minority on deserts (9%) (Durant *et al.*, 2012). The Sahara, the world's largest desert, harbours iconic large mammal biodiversity, yet has attracted very little scientific attention. Over the same period, only 31 ISI ecology papers were focused on aspects of Saharan biodiversity† Moreover, a recent review by Brito *et al.* (2013) confirms that there has been little biodiversity research in the Sahara over the last decade and that the central Sahara has been almost entirely neglected.

The lack of scientific attention given to desert biodiversity is mirrored by a lack of financial support. Although the Saharan nations cover 43% of Africa's land mass, they only received 12% of Global Environment Facility funding to Africa over the period 1991–2009 (Global Environmental Facility, 2010; Durant *et al.*, 2012). Similarly, only 1% of funds provided by the UK's Darwin Initiative between 1992 and 2008 went to projects in desert biomes, compared with 23% to forests over the same period (Hardcastle, 2008; Durant *et al.*, 2012). Such low levels of research and funding can allow key species to disappear from desert landscapes largely unreported and unnoticed by conservationists and scientists.

Two workshops organized by the Zoological Society of London and the Wildlife Conservation Society in 2010 and 2012 have shed long overdue light on the status of large vertebrate biodiversity in the Sahara. These workshops used an expert-based mapping process (Sanderson *et al.*, 2002; IUCN/SSC, 2006, 2007a,b, 2008, 2012) to establish current areas of known resident range for 14 species and subspecies of large vertebrate found in the Saharan region. These taxa include all of the large herbivores and all but one of the large carnivores found in the region. The presence of both groups is indicative of effective ecosystem function and management (Estes *et al.*, 2011; Fritz *et al.*, 2011; Poisot *et al.*, 2013). The single species not included in the analysis was the striped hyena (*Hyaena hyaena*), for which little distributional information is available.

Participants in the mapping process were species experts and protected area managers who contributed data on the species' distribution and status, drawing upon their own and their colleagues' information and experience. In this process, the Sahara was defined as land receiving <250 mm annual rainfall, covering a total area of 9,775,572 km^2. Each species was mapped in turn. All land formerly occupied by the species before major anthropogenic change (agreed to be prior to *c.* 1800) was considered to fall inside the historical range. For many areas, detailed historical data on distribution were available; elsewhere, historical distribution was estimated based on the species' broad habitat requirements. Point locations of species presence were used to help delineate geographic range polygons of current resident range. Current

†ISI Web of Science http://wok.mimas.ac.uk, 17 Oct 2013, search, subject area ecology, including 'Sahara'. 130 publications found of which 31 included information on biodiversity in the Sahara desert (most referred to sub-Saharan Africa).

range was land where participants agreed that the species was known or was highly likely to be still resident. This was generally defined as land where there was evidence of the species being present within the last 10 years. However, for areas where there had been little or no ground-based surveying in recent years, resident range could include land, which contained suitable habitat and/or prey, provided it was connected to the known range of the species. At the workshop, maps were reviewed and modified through discussion among participants. The maps were circulated to participants unable to attend the workshop in person, in order to reach an expert consensus on current and historical distributions. These maps were then used to evaluate the proportions of each species' current geographic range compared with historical range.

Of the 14 species and subspecies assessed, 10 (71%) are endemic to the Sahara or the wider Sahelo–Saharan 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 (shown in Fig. 1) clearly show a massive collapse in large vertebrate distributions across the region. Thirteen of the 14 species have disappeared from 66% or more of their historical Saharan range, and nine species have disappeared from 90% or more of their range (Table 1, Fig. 1). Shockingly, half of the 14 species are either regionally extinct or confined to 1% or less of their historical range. The range collapse of the species still extant raises serious concerns for their future survival in the region; only the Nubian Ibex (*Capra nubiana)* still inhabits most of its historical range, but even this species is classified as vulnerable, due to numerous threats throughout its range, including widespread hunting (Alkon *et al.*, 2008).

Difficulties in access for conservationists and other key actors due to lack of roads and a hostile terrain, exacerbated by past and ongoing instability across the region, have undoubtedly contributed to the declines of this iconic desert fauna (Brito *et al.*, 2013). Widespread and unsustainable hunting is also reported to have posed a significant threat to vertebrates across the region (Beudels-Jamar *et al.*, 2006; Brito *et al.*, 2013). However, it is difficult to escape the conclusion that lack of financial support and scientific attention

Table 1 Percentage loss of range compared with historical range for 14 species of large vertebrate in the Saharan region. Estimates calculated from maps in Fig. 1.

Species	Scientific name	IUCN Red List status	Endemic to the Sahelo–Saharan region?	Historical range (km^2)	Current known resident range (km^2)	% range loss
Scimitar-horned oryx	*Oryx dammah*	Extinct in the Wild	Yes	1,543,784	0	100
Addax	*Addax nasomaculatus*	Critically Endangered	Yes	6,911,931	47,155	99
Bubal hartebeest	*Alcelaphus buselaphus buselaphus*	Extinct	Yes	500,969	0	100
Dorcas gazelle	*Gazella dorcas*	Vulnerable	Yes	9,739,599	1,357,723	86
Nubian ibex	*Capra nubiana*	Vulnerable	No	320,636	287,902	10
Barbary sheep	*Ammotragus lervia*	Vulnerable	Yes	2,361,570	535,031	77
Slender horned gazelle	*Gazella leptoceros*	Endangered	Yes	1,298,549	182,005	86
Cuvier's gazelle	*Gazella cuvieri*	Endangered	Yes	279,525	96,330	66
Dama gazelle	*Nanger dama*	Critically Endangered	Yes	3,616,260	23,720	99
North African ostrich	*Struthio camelus camelus*	Least Concern*	Yes	9,421,600	18,710	99.8
Leopard	*Panthera pardus*	Near Threatened	No	891,817	29,221	97
Saharan cheetah	*Acinonyx jubatus hecki*	Critically Endangered	Yes	8,360,570	813,947	90
African wild dog	*Lycaon pictus*	Endangered	No	2,606,295	0	100
Lion	*Panthera leo*	Vulnerable	No	738,644	0	100

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

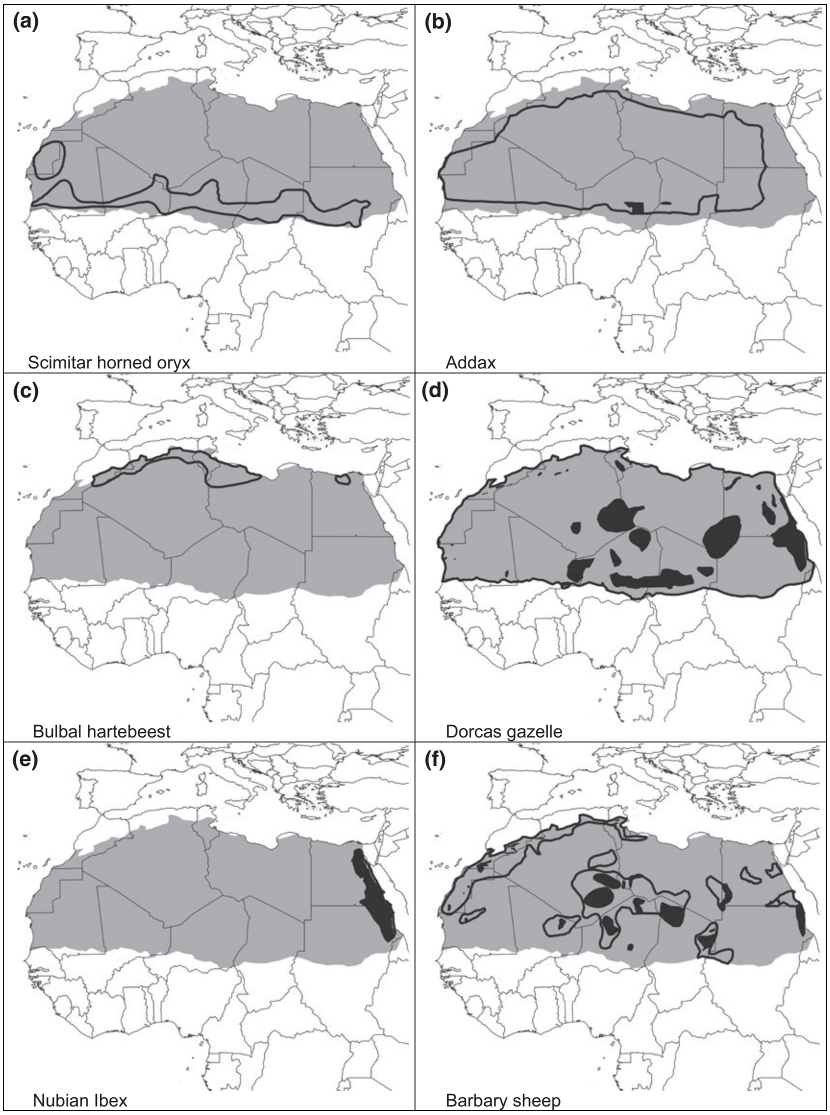

Figure 1 Maps of range loss for 14 species in the Sahara. The Saharan region was defined as land where annual rainfall was below the 250 mm isohyet (grey shading) obtained from wordclim.org. Historical range (thick black line) refers to land formerly occupied by the species prior to major anthropogenic change, that is, prior to *c.* 1800. Resident range (black shading) refers to land supporting 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 such areas is not expected to significantly change the range loss estimates in Table 1. Note also that maps do not depict resident or historical range outside the Sahara, although not all species are endemic to the desert. Small fenced reserves where populations are not self-sustaining are not depicted on these maps.

have also played a role (e.g. Laurance, 2013). Despite this, there have been some successes. Niger is to be congratulated on its recent proclamation of the 97,000 km^2 Réserve Naturelle Nationale du Termit et du Tin Toumma, which harbours around 150 of the world's 200 remaining wild addax and one of a handful of remaining populations of dama gazelle. Chad also deserves support for its programme to bring back scimitar-horned oryx, currently extinct in the wild, to the Ouadi Rimé-Ouadi Achim Game Reserve (Bemadjim *et al.*, 2012). These successes result from support from organizations such as the Convention on Migratory Species (CMS) (UNEP/CMS, 1999; Beudels-Jamar *et al.*, 2006), the Environment Agency Abu Dhabi, the Sahelo–Saharan Special Interest Group and the Sahara Conservation Fund, which have stimulated a wide range of important conservation efforts in the region.

All the Saharan nations require additional support if they are to safeguard biodiversity effectively across such enormous landscapes, particularly in the context of escalating conflicts in the region (Brito *et al.*, 2013). This can only be obtained if the conservation and scientific communities increase their focus on biodiversity in these 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 (Brito *et al.*, 2013). Given low human densities and that over 90% of tropical arid and hyperarid lands remain uncultivated (Mortimore *et al.*, 2009), management of natural resources in desert ecosystems may 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 (Brito *et al.*, 2013), suggesting that key pressures are likely to be habitat loss or degradation and hunting or persecution by humans (Safriel *et al.*, 2005).

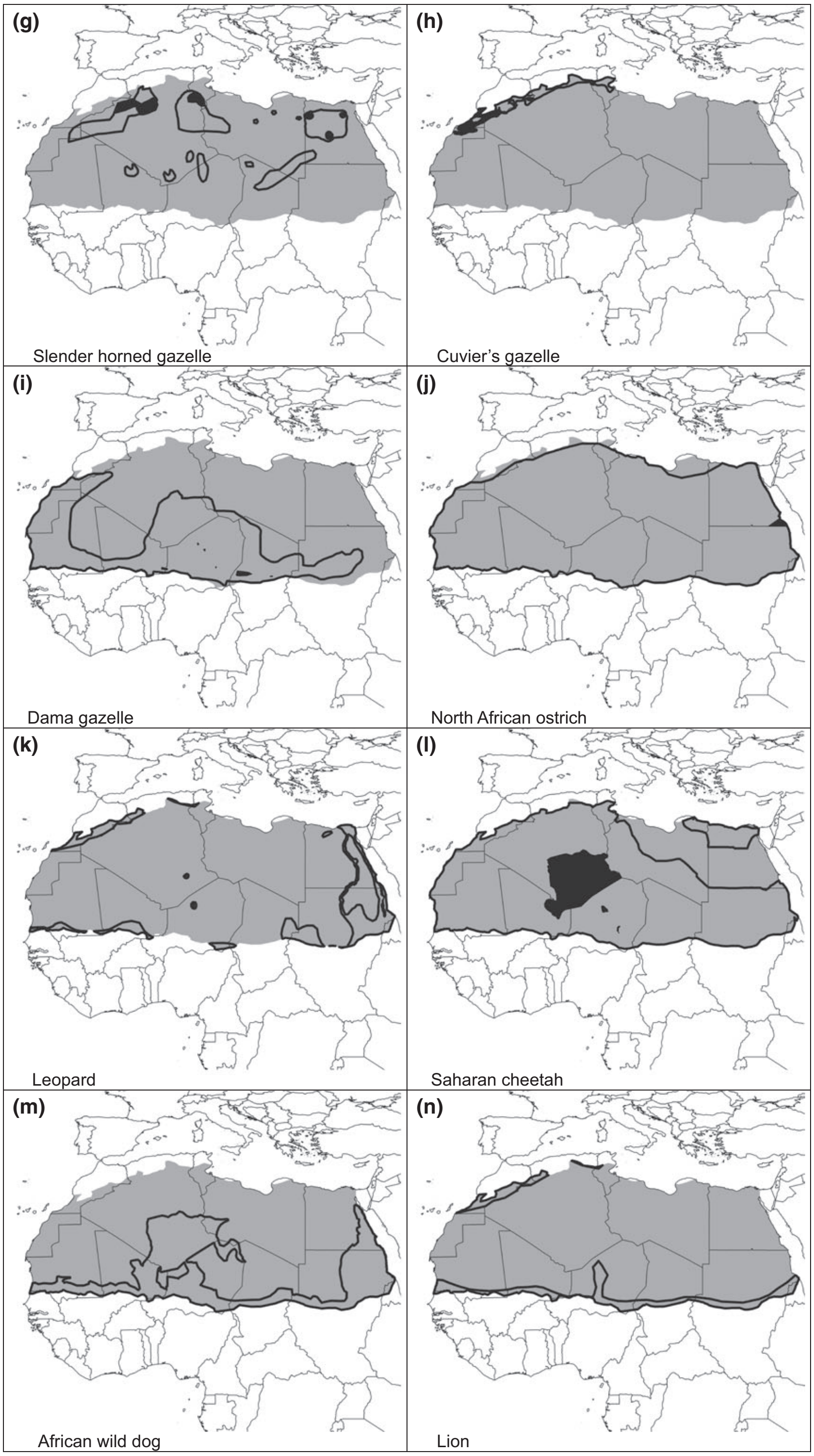

Figure 1 Continued.

There is increasing evidence of a need for a paradigm shift in approaches to biodiversity conservation and human development in desert systems (Mortimore *et al.*, 2009; IIED, 2013). Large herbivores living in deserts are nomadic and wide-ranging, able to respond quickly to sporadic rainfall events and to take advantage of the nutrients provided by fresh growth (Beudels-Jamar *et al.*, 2006). Desert-dwelling nomadic pastoral people mimic the mobility adaptations of the wildlife with which they share their land, enabling them also to take advantage of variable rainfall and to exploit grazing resources at the peak of their productivity (McCabe, 2004; Homewood, 2009). Unfortunately, however, there is increasing pressure for people to settle through expanding policies of well construction and efforts to increase agriculture in deserts, in the mistaken belief this is the route to food security (IIED, 2013). Such changes in land use in unpredictable low rainfall environments have led to widespread desertification, which have, in turn, increased the vulnerability of the people and livestock who inhabit these systems.

Accommodating mobility of both wildlife and people presents significant political and social challenges, particularly in areas of conflict and where transboundary movements are extensive, such in many areas of the Sahara. However, surmounting these challenges and accepting that mobility is key to efficient use of dryland resources are essential precursors to the sustainable management of desert ecosystems (IIED, 2013). This is also increasingly critical as we approach an era where climate change is expected to exacerbate drought in many regions of the globe (IPCC, 2012). While biodiversity hotspots are clearly 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 comparatively low (Loarie *et al.*, 2009). Adaptation to the impacts of climate change in deserts is thus likely to be particularly urgent. 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.

2014 is the halfway point in the United Nations Decade for Deserts and the Fight against Desertification and the fourth 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 to enshrine the need for mobility of both people and wildlife. 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 prioritize applied research into the conservation of biodiversity and the restoration of ecosystem function in deserts, including restocking of wildlife, 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 for 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. Restoring ecosystem function and implementing sustainable management of desert ecosystems will not only benefit biodiversity and some of the world's most impoverished and marginalized human communities, but will also help to mitigate against global climate change.

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BIOSKETCH

Sarah M. Durant is a conservation scientist with research interests in carnivore conservation, biodiversity monitoring, human wildlife coexistence and conservation management. Coauthors were participants in the ZSL desert declines workshop and/or the strategic planning workshop for conservation of cheetah and African wild dog in western, central and northern Africa.

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