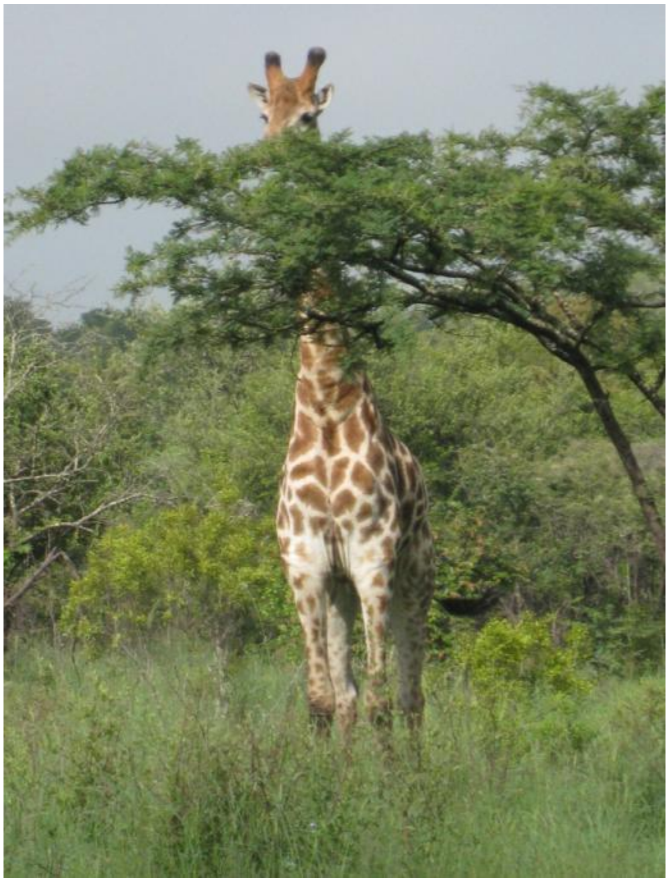

CLIMATE-CHANGE VULNERABILITIES AND ADAPTATION STRATEGIES FOR AFRICA'S CHARISMATIC MEGAFAUNA

HEINZ CENTER FOR SCIENCE ECONOMICS & ENVIRONMENT

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The phrase "African animals" brings to mind elephants, lions and other iconic large mammals often referred to as "charismatic megafauna." The powerful appeal of these animals is demonstrated in the many African wildlife documentaries on television and enduring public support for zoos and museums featuring African animals. Although these charismatic megafauna are only one piece of the ecological picture, many conservation non-governmental institutions (NGOs) leverage their symbolic power to encourage donations. Countries in sub-Saharan Africa garner a variety of economic benefits from their iconic wildlife. International tourists going on safari to see the famous "Big Five" (elephant, buffalo, leopard, lion, and either black or white rhinoceros) are a major source of revenue. Sport hunting and game ranching are also important industries dependent on the conservation of African wildlife.

The broad interest in Africa's megafauna for conservation, tourism, hunting and game ranching has motivated a vast amount of research into their biology, ecology and management. These are some of the best-studied animal species on the planet; however, they have not yet been the focus of much climate change research. Other than a few isolated studies, little has been done to compare the potential effects of climate change across these species. In this report, we combine basic information about the biology of 20 African large mammal species with information about projected climate impacts in sub-Saharan Africa to conduct an initial vulnerability assessment for these species. The vulnerability of a species to climate change is a factor of the extent of change to which it will be exposed, its sensitivity to the altered conditions, and its ability to adapt (Glick et al. 2011). By understanding the shared vulnerabilities across species, wildlife managers will be best-equipped to develop common adaptation strategies for the greatest benefit. In the perennially cash-strapped field of conservation, such efficiency is vital.

> "If we do not do something to prevent it, Africa's animals, and the places in which they live, will be lost to our world, and her children, forever."
> – Nelson Mandela

Based on an extensive literature review that examined information about the ecology and physiology of each species, this study outlines: how each of these species may be vulnerable in the face of climate change; aspects of their biology or life history that may make them more resilient; and suggested adaptation strategies. The Intergovernmental Panel on Climate Change (IPCC 2012) defines adaptation in natural systems as: the process of adjustment to actual climate and its effect; human intervention may facilitate adjustment to the expected climate.

The initial review of climate vulnerabilities for the African megafauna presented in this report indicates that there are several key areas of vulnerability shared by many of these species. Chief among these is the need for surface water. Many of the species included in this report are water-dependent, and many must drink daily. Heat stress is another common vulnerability shared across many of the African wildlife species included in this report. The lack of habitat connectivity has been mentioned as a contributing element to climate vulnerability in many of the African megafauna species. Some other factors that may make species vulnerable include: loss of a food source, specific range requirements, reproductive biology limitations, population growth, genetic bottlenecks, and interspecies and intraspecific interactions. Finally, many of the wildlife species discussed in this report are threatened much more severely by factors other than climate change. Disease, particularly anthrax but also rabies and distemper, has the potential to affect many iconic African wildlife species. In addition, illegal harvest and poaching continue to threaten such dangerously imperiled species as the two rhinoceroses and the African elephant.

To help counter these stressors, managers can implement what are known as adaptation strategies (Heller and Zavaleta 2009; Mawdsley et al. 2009), conservation approaches that are designed to assist wildlife populations and wildlife habitats respond positively to the challenges posed by climate change. Possible adaptation strategies for the wildlife species in this report might include: provision of water or shade, improving habitat connectivity, captive breeding or game ranching, translocation and reintroduction.

INTRODUCTION

For people around the world, the phrase "African animals" conjures up images of elephants, lions, giraffes and other iconic large mammals that are known collectively to scientists as the "charismatic megafauna." As the term implies, these are animals that appeal directly to humans due to a combination of their uniqueness, size, beauty, ferocity and mystique. This dynamism holds great power – witness the popularity of African wildlife documentaries on television and the enduring public support for zoos and museums featuring these animals – which inspires people worldwide to provide financial support for wildlife conservation and significant revenue for the countries in sub-Saharan Africa.

Although the African megafauna are only a piece of the larger ecological picture, they usually serve as the standard bearers for conservation efforts on the continent. These species and their well-being matter deeply to people all over the world, who in turn contribute generously to charities established to help conserve these animals. In 2006, non-governmental organizations (NGOs) spent US$143million, overhead not included, on wildlife conservation activities in sub-Saharan Africa (Brockington & Scholfield 2010). Of that total, US$46million and US$34million were spent in southern Africa and eastern Africa respectively (Brockington & Scholfield 2010). The fact that six of the ten largest conservation NGOs active in sub-Saharan Africa have a charismatic species for their logo is evidence of these animals' symbolic power.

Tourists come from around the globe to see Africa's iconic animals in their natural habitats. International tourism is a major part of the economy for sub-Saharan countries that have both wildlife and the appropriate infrastructure to support tourism. Over 50% (nearly 770,000) of foreign tourists to South Africa visited wildlife attractions in 2010 (SA Tourism Departure Surveys). National parks and protected areas make up over 25% of land in Tanzania, where over 714,000 international tourists yielded US$1.16 million of revenue (Tanzanian Ministry of Natural Resources and Tourism 2009). Tourism is estimated to account for 19.9% and 6.6% of GDP in Namibia and Botswana respectively (Namibian Ministry of Environment and Tourism 2010; World Travel and Tourism Council 2011). Tourists on safari hope to see the famous "Big Five:" elephant, buffalo, leopard, lion, and either black or white rhinoceros. Although these species were initially dubbed the Big Five because they were the most dangerous to hunt, seeing and photographing these animals has become an essential part of the modern tourist experience. Booth (2010) shows the significance of income generated from all nature tourism and for hunting tourism specifically (see Table 1).

Table 1.

	Income from all nature tourism (all figures from 2000-2001)	**Approximate gross value of hunting tourism** (dates for individual figures indicated)	
Country	US$ Millions	Gross Income (US$ Millions)*	Date
Botswana	131.3	12.6 40.0	2000 2008
Mozambique	8.4	5.0	2008
Namibia	247.6	9.6	2004
South Africa	2,298.8	68.3	2003/2004
Tanzania	299.9	39.2 56.3	2001 2008
Zambia	72.8	3.6	2002
Zimbabwe	143.5	18.5 15.8	2000 2007

* Data not adjusted for inflation
Source: Adapted from Booth 2010

There is a long tradition of sport hunting of large mammals in sub-Saharan Africa, as immortalized in the writings of Theodore Roosevelt, Frederick Courteney Selous and Ernest Hemingway. Sport hunting continues to be a major industry and source of economic growth in many African countries. According to the wildlife trade monitoring group TRAFFIC, sport hunting in the late 1990s generated annual revenues of US$29.9 million in Tanzania, US$28.4 million in South Africa, US$23.9 million in Zimbabwe, US$12.6 million in Botswana and US$11.5 million in Namibia (Barnett and Patterson 2006). More recent estimates (Pickrell 2007) suggest that hunters spent approximately US$200 million per year in the 23 African countries that allow sport hunting. Per-person expenditures in Africa average more than $10,000 for sport hunters, who often travel to remote areas (Pickrell 2007). In addition to travel expenses, hunters must also pay large trophy fees in order to pursue their quarry.

Over US$18 million in fees were collected from foreign hunters in 1999 (see Table 2); US$3.5 million of this was for Big Five species (Hoogkamer 2001). More recent data suggests that the hunting industry has become even more reliant on the charismatic species for the majority of its revenue (Barnett and Patterson 2006). Although some environmentalists are opposed to hunting on principal, the revenue potential of sport hunting provides a strong financial incentive for conserving wildlife. Funds raised from trophy fees can benefit local communities and local habitat and wildlife conservation efforts.

Table 2.

Number of animals hunted in 1999 by foreign hunters and trophy fees generated in Eastern and Southern Africa			
Species	Total	Average Value (US$)	Total Value (US$)
Lion	95	13,000	1,235,000
White Rhino	43	25,000	1,075,000
Elephant	20	20,000	400,000
Buffalo	150	4,500	675,000
Leopard	69	3,000	207,000
Big 5 Subtotal	**377**		**3,592,000**
All other specific species from source table not shown here	21,592		13,477,210
Other species (71)—as listed in table	2,562		1,291,375
TOTAL	**24,526**		**18,360,585**
Note: average value is based on average price of species when offered for hunting Adapted from: C. Hoogkamer, SAPHCOM, in lit to TRAFFIC East/Southern Africa, July 2001			

Game farming, or game ranching, is also an important industry in southern Africa. Methods have been developed for ranching or farming many of the large, charismatic wildlife species, especially antelope and the Big Five (Du Toit et al. 2002). In the Republic of South Africa, over 9,000 farms are used for wildlife production and an additional 15,000 are used for combined wildlife and livestock production. Game ranches yield valuable meat products as well as feathers, hides and leather goods. On marginal lands, native wildlife (game) can be more efficient than cattle at utilizing available food resources. Many game species also have lower impact on sensitive soils and vegetation communities than do cattle and other domestic livestock. In addition, native species are better adapted to withstand the effects of drought than domesticated species. Game ranches often also support sport hunting activities. In 2007, game hunting on private lands in South Africa yielded nearly US$26 million and almost US$27 million came from sales of live game (Statistics South Africa 2010).

Regardless of the use, it is clear that charismatic megafauna are of great economic importance. Kojwang (2010) considered both consumptive (e.g., hunting tourism, live game) and non-consumptive (e.g., wildlife viewing) uses when he estimated the overall value of wildlife in Namibia. His results reflect the values of different wildlife utilization and the actual stock levels of each species to determine an overall value of each as an asset (see Table 3).

The broad interest in Africa's megafauna for conservation, tourism, hunting and game ranching has motivated a vast amount of research into their biology, ecology and management. These are some of the best-studied animal species on the planet, and we know a great deal about their basic biology, life history and ecology. Thanks to zoos, game farms and national park biologists, methods for managing these species under captive, semi-wild and wild conditions are all well developed. Unlike many of the world's wildlife species that are managed by "benign neglect," these animals are actively managed in many of the places where they still occur. This extensive knowledge base is what makes it possible for us to estimate how these species might respond to climate change, and also predict how managers and biologists might be able to implement specific adaptation measures to help these animals respond positively to changes in the African climate.

Table 3.

Monetary wildlife asset account 2004: Estimated asset value for wildlife in Namibia by species	
Big Five	US$ Millions
Buffalo	13.143
Elephant	67.996
Leopard	16.553
Lion	3.124
Rhino, black	24.552
Rhino, white	2.068
Subtotal	**127.436**
Other species profiled in this report	US$ Millions
Cheetah	7.048
Eland	33.167
Gemsbok	250.269
Giraffe	17.080
Hippo	5.353
Kudu	213.089
Wildebeest, blue	21.080
Zebra, plains	41.295
Zebra, mountain	79.484
Subtotal	**667.865**
Subtotal for all other species listed below*	**743.817**
TOTAL	**1,539.118**

* Hartebeest, red; Impala, black-faced; Impala, common; Lechwe; Ostrich; Roan; Sable; Springbok; Tsessebe; Warthog; Waterbuck

Source: Adapted from Kojwang 2010

The threat of climate change has become an overwhelming concern in the field of wildlife conservation. Projected changes in the world's ecosystems are already being observed (Root et al. 2003; Hughes 2000). For example, the timing of many bird migrations and the range of their occurrence has altered around the world as a result of higher temperatures. According to the Intergovernmental Panel on Climate Change (IPCC 2007) these changes are occurring at a faster than expected rate, particularly in southern Africa. The numbers of mammal species in the national parks in sub-Saharan Africa could decline by 24 to 40% (IPCC 2007). One study predicts that 66% of animal species in South Africa's Kruger National Park could go extinct (Erasmus et al. 2002). From the perspective of the tourism industry alone, such a loss would be devastating to the economy. A study in Namibia showed a positive correlation between the richness of large wildlife species and income from ecotourism and trophy hunting (Naidoo et al. 2011).

Despite the great importance of Africa's charismatic megafauna, they have not yet become the focus of much climate change research. In fact, most of what we know about the impact of climate change thus far in sub-Saharan Africa is based on birds; we know comparatively little about other groups (Robinson 2008). Other than a few isolated studies, little has been done to compare the potential effects of climate change across the large African mammal species. Detailed computer modeling studies of climate change impacts on the African charismatic megafauna are lacking. In this report, we combine basic information about the biology of each of 20 African large mammal species with information about projected climate impacts in sub-Saharan Africa in an initial vulnerability assessment for these species. The vulnerability of a species to climate change is a factor of the extent of change to which it will be exposed, its sensitivity to the altered conditions and its ability to adapt (Glick et al. 2011). By understanding the shared vulnerabilities across species, wildlife managers will be best-equipped to develop common adaptation strategies for the greatest benefit. In the perennially cash-strapped field of conservation, such efficiency is vital.

METHODS

In addition to the Big Five, we selected the following list of large mammal species based on their importance to biodiversity conservation, tourism, sport hunting and game farming (see Table 4). Based on an extensive literature review that examined information about the ecology and physiology of each species, this study outlines: how each of these species may be vulnerable in the face of climate change; aspects of their biology or life history that may make them more resilient; and suggested adaptation strategies. The IPCC (2012) defines adaptation in natural systems as: the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to the expected climate.

Table 4.

Species Profiled in this Report	
Common Name	Scientific Name
African Elephant	*Loxodonta africana* (Blumenbach)
African Wild Dog	*Lycaon pictus* (Temminck)
Bongo	*Tragelaphus eurycerus* (Ogilby)
Cape Buffalo	*Synverus caffer* (Sparrman)
Cheetah	*Acinonyx jubatus* (Von Schreber)
Common Eland	*Tragelaphus oryx* (Pallas)
Giraffe	*Giraffa camelopardalis* (Linnaeus)
Gemsbok	*Oryx gazella* (Linnaeus)
Greater Kudu	*Tragelaphus strepsiceros* (Pallas)
Hippopotamus	*Hippopotamus amphibious* (Linnaeus)
Leopard	*Panthera pardus* (Linnaeus)
Lion	*Panthera leo* (Linnaeus)
Okapi	*Okapia johnstoni* (Sclater)
Rhinoceros, Black	*Diceros bicornis* (Linnaeus)
Rhinoceros, White	*Ceratotherium simum* (Burchell)
Wildebeest, Black	*Connochaetes gnou* (Zimmermann)
Wildebeest, Blue	*Connochaetes taurinus* (Burchell)
Zebra, Grevy's	*Equus grevyi* (Oustalet)
Zebra, Mountain	*Equus zebra* (Linnaeus)
Zebra, Plains/Burchell's	*Equus burchelli* (Boddaert)

We based our climate projections for sub-Saharan Africa on the latest report of the IPCC. Regional projections indicate that both the temperature and precipitation will increase in eastern Africa; whereas, the temperature will increase but precipitation will significantly decrease in southern Africa (IPCC 2007). It is important to note that the annual averages shown below (Table 5) mask some extreme seasonal changes to temperature and precipitation predicted for the 21st century. The models agree that all regions of Africa will have more frequent periods of extreme temperatures (IPCC 2012). In fact, 100% of all seasons will be extremely warm by the end the century (IPCC 2012). Although overall precipitation will likely decrease, eastern and southern Africa will also experience more frequent extreme precipitation events (IPCC 2012).

Table 5.

Regional averages of projections from a set of 21 global models for 2080-2099					
		Temperature Change °C		Precipitation Change %	
		Minimum	Maximum	Minimum	Maximum
East Africa	Annual	1.8	4.3	-3	25
South Africa	Annual	1.9	4.8	-12	6
West Africa	Annual	1.8	4.7	-9	13
Data excerpted from Table 11.1 in IPCC 2007					

The vegetation and landscape of sub-Saharan Africa will change in response to these climate scenarios. The IPCC can project with high confidence that the arid and semi-arid land in Africa will increase 5 to 8% (IPCC 2007). Grassland and open woodlands are the habitat for most African wildlife in eastern and southern Africa (Chidumayo 2011). Such extremes will make woodlands more susceptible to bush fires, which can destroy flora and fauna (IPCC 2007).

Vulnerability is defined "the propensity or predisposition to be adversely affected" by climatic change (IPCC 2012). There are three factors that contribute to the overall vulnerability of a species to climate change: exposure, sensitivity and adaptive capacity (Glick et al. 2011). The predicted climate change in Africa may have a wide range of direct effects on species. Some examples include: changes in rainy and dry seasons, altered species distribution and habitat, shifts in breeding season and changes to population growth rates (Chidumayo 2011). The range of each species will dictate their potential exposure to climate change. In addition, climate change may indirectly affect a species as a result of changes in the composition of the wider community (Chidumayo 2011). The adaptive capacity, or resilience, of a species depends upon its ability to tolerate and/or adjust to climate change. Table 6 below contrasts how different species might respond to a single effect of climate change.

Table 6.

Summary of Elements of Vulnerability and Resilience to Climate Change		
	Vulnerability	Resilience
Heat	Must have shade to stay cool	Can tolerate heat; thermoregulation mechanism does not require water
Water	Must have access to water; cannot move far from source of surface water	Can go several days without water and/or can survive on metabolic water from food
Food	*Grazers:* Limited diet; food at risk from climate change; dependent on lush vegetation	*Browsers:* Can consume a variety of species; can digest dry vegetation
Predation	Typical prey population reduced due to climate; unable to switch to other prey	Not dependent on only a few types of prey; can switch prey as needed
Vegetation	Need cover for hunting or hiding from predators	Not constrained to areas with vegetation cover
Disease	Susceptibility to diseases likely to increase	Immune or resistant to many diseases
Distribution	Range restricted; extirpation more likely with small number of subpopulations	*Currently broad distribution:* stronger metapopulation *Historically broad distribution:* proven survival in range of conditions
Migration/Dispersal	Does not migrate or cannot due to barriers	Can move if necessary
Range Requirements	Large area required and/or limited area available; adapted to specific habitat type	Does not require a large area; habitat flexibility
Reproductive Biology	Seasonal breeding; adequate supply of water needed for successful breeding	Breeding not restricted to a specific season; can breed and nurse young despite lack of water
Population Trend-current	Declining; must always remain at low population density due to ecological factors	Stable, increasing
Population Growth-potential	Slow population growth makes it difficult to recover numbers or re-populate a new area	Fast population growth allows for recovery from loss due to climate change or related predation
Genetic Bottleneck	Previous loss in genetic diversity makes populations even less resilient	Broad genetic diversity best equipped to deal with environmental changes
Interspecies Interactions	Loss of prey to other carnivores; food competition with other herbivores	Little overlap in diet with other species
Intraspecific Interactions	Territoriality; fighting, especially over water and/or food	Tolerant of others if territories overlap
Human Interactions	Poaching, human-wildlife conflict and/or habitat loss are serious threats	Little interaction with humans and/or are able to share habitat with humans

RESULTS AND DISCUSSION

The initial review of climate vulnerabilities for the African megafauna presented in this report indicates that there are several key areas of vulnerability shared by many of these species. Chief among these is the need for surface water. Many of the species included in this report are water-dependent, and many must drink daily. Some (e.g., African elephant and hippopotamus) have enormous water requirements that can best be met by large bodies of water such as lakes and rivers. Other species are water-independent or only semi-dependent on surface water. Heat stress is another common vulnerability shared across many of the African wildlife species included in this report. The lack of habitat connectivity has been mentioned as a contributing element to climate vulnerability in many of the African megafauna species. Since the period of European colonization, populations of many large mammal species have become increasingly fragmented across the landscape, with the possibility of lost genetic diversity and localized extinction. This trend has apparently accelerated in recent decades for iconic species such as African lion, African elephant and hippopotamus. Finally, many of the wildlife species discussed in this report are threatened much more severely by factors other than climate change. Disease, particularly anthrax but also rabies and distemper, has the potential to affect many iconic African wildlife species. Illegal harvest and poaching continue to threaten such dangerously imperiled species as the two rhinoceroses and the African elephant.

To help counter these stressors, managers can implement what are known as adaptation strategies (Heller and Zavaleta 2009; Mawdsley et al. 2009), conservation approaches that are designed to assist wildlife populations and wildlife habitats respond positively to the challenges posed by climate change.

Possible adaptation strategies for the wildlife species in this report might include:

- **Provide water** – Ensuring adequate water supplies for wildlife species, particularly in smaller parks and natural areas, is a critical adaptation strategy for many African wildlife species. Fortunately, the technology for providing artificial water sources is well developed and has been implemented already and tested at large scale in many national parks and other natural areas of sub-Saharan Africa. Boreholes, tanks and other artificial watering sources have been employed in many wildlife conservation areas and game reserves, particularly in areas where animals are cut off by fencing or other human developments from natural water sources. Such developments may become increasingly important features of wildlife management in sub-Saharan Africa. However, it should be noted that water provision can create artificially high densities and concentrations of certain wildlife species (Gaylard et al. 2003). This can have deleterious repercussions for the other wildlife in the area.
- **Provide shade** – Adequate shade to prevent overheating is required by many African wildlife species, particularly during summer daylight hours when solar thermal energy is at its maximum. Providing shade in larger wildlife conservation areas generally involves ensuring adequate densities of trees, especially in riparian areas where many wildlife species congregate. On a smaller scale, awnings and other physical shading structures are commonly used in game ranches and intensive wildlife production areas to provide animals with adequate shade.
- **Improve habitat connectivity** – Increasing the connections between existing wildlife conservation areas is necessary in order to prevent genetic isolation and local population extirpation, as well as to ensure maximal flexibility for species to adapt to changing climates. Increasing connectivity to facilitate wildlife dispersal may be as straightforward as removing game fences between adjoining conservation areas or as complex as fully restoring vegetation along potential animal movement corridors.
- **Captive breeding or game ranching** – Captive breeding is often viewed as a conservation strategy of last resort in the USA and Europe. However, the success of game ranching and other approaches in sub-Saharan Africa suggests that captive breeding should certainly be considered as a viable climate adaptation strategy for the continent's charismatic megafauna. Techniques for captive breeding or game ranching are already well developed for many large mammalian species, particularly antelope and other game species, including the Big Five. Guidebooks and manuals for captive rearing, game ranching and intensive production are available from commercial publishers and game ranching associations that cover many of the large mammals in sub-Saharan Africa.

- **Translocation** – There are intense debates in the scientific literature about the wisdom and propriety of translocation as a strategy for helping species to adapt to climate change. In sub-Saharan Africa, there is a long and positive history of translocation as a method for re-introducing animals into portions of their historic range, and also as a method for introducing animals into novel areas for game ranching purposes. Techniques for translocating species are well developed and have been extensively field-tested and discussed in the scientific literature.
- **Reintroduction** – As with translocation, reintroduction as a strategy for climate adaptation has proven to be somewhat controversial in the literature. In standard conservation practice, species reintroductions are usually predicated on the identification of unoccupied areas of suitable habitat that can support new populations of a given species. However, as climatic parameters change, the suitability of particular habitat patches may also change, potentially in directions that render these areas less suitable as habitat for individual wildlife species. Moving forward, managers should consider projections of future habitat suitability, as well as current habitat suitability, before undertaking large or expensive reintroduction projects. Methods for species reintroduction have been developed for many species of African wildlife, including many of the charismatic megafauna.
- **Habitat Protection** – Conservation of remaining areas of suitable habitat for Africa's charismatic megafauna species is a key strategy to facilitate adaptation to climate change. Particular attention should be paid to ecological communities and vegetation types that are not already well represented within reserve networks.
- **Manage other stressors** – Reduction of other threats and stressors is commonly recommended in the climate adaptation literature. By reducing other threats and stressors, managers can help to ensure that wildlife have maximum flexibility in adapting to climate change through natural biological pathways. Common stressors identified for many of the African wildlife species included in this report are illegal harvest, wildlife disease and human-wildlife conflicts. Yet to only focus on "business as usual" is not a viable option. The rapidly changing climate presents an onslaught of challenges that must be confronted head on, rather than as subsidiary concerns.

Table 5.

Strategies for Managing the Effects of Climate Change on Wildlife and Ecosystems	
Land/Water Protection and Management	1. Increase the amount of protected areas 2. Improve representation and replication within protected area networks 3. Manage and restore existing protected areas to maximize resilience 4. Design new natural areas and restoration sites to maximize resilience 5. Protect movement corridors and "stepping stones" 6. Manage and restore ecosystem function, rather than focusing on specific components (species, community assemblages) 7. Improve the matrix—increase landscape connectivity and permeability to species movement 8. Reduce non-climate stressors on natural areas and ecosystems
Species Conservation	9. Focus conservation resources on species that might become extinct 10. Translocation or assisted dispersal of species 11. Establish captive populations of species that would otherwise go extinct 12. Reduce pressures on species from sources other than climate change
Monitoring and Planning	13. Evaluation of existing monitoring programs for wildlife and key ecosystem components to determine: a) how these programs will need to be modified to provide management-relevant information on the effects of climate change b) what new monitoring systems will need to be established in order to address gaps in our knowledge of climate effects 14. Incorporate predicted climate change impacts into species and land management plans, programs and activities 15. Develop dynamic landscape conservation plans 16. Ensure that wildlife and biodiversity needs are considered as part of the broader societal adaptation process
Law and Policy	17. Review existing laws, regulations and policies regarding wildlife and natural resource management to insure that these instruments provide managers with maximum flexibility in addressing the effects of climate change 18. Propose new legislation and regulations as needed to provide managers with the flexibility, tools and approaches needed to effectively address climate change impacts
	Source: The Heinz Center 2008

FUTURE DIRECTIONS

This report presents information about the factors that contribute towards climate-change vulnerability and resiliency for a number of large African large mammalian species. We plan to produce further iterations of this report to include more animals that are valuable for ecotourism, national parks management, game ranching and commercial sport hunting. For example, we are interested in increasing the coverage of antelope and carnivore species because of their central role in game ranch and sport hunting activities. We also plan to increase our geographic coverage of species in tropical western and central Africa, where climate-change effects are expected to be especially pronounced. In addition to the elevated risk of extinction from climate change, current stressors such as bushmeat harvest, habitat loss and habitat fragmentation already threaten numerous large mammal species. In particular, great apes in the Congo basin are at risk from the concatenation of all these factors.

We hope that this report will help to inspire increased study of the effects of climate change on African megafauna. In particular, dynamic modeling approaches which link wildlife population demographics and climate change are well-developed (IPCC 2007), and could easily be applied to the species in this report at international, regional or local scales. For wildlife managers who are working in a particular national park or with a single captive population, local-scale analyses that take into account downscaled climate information are likely to prove to be especially useful management tools.

Finally, we hope that this report, and the information contained in it, is useful for the staff members of the wildlife management agencies in African countries, who are already facing the effects of climate change. The information presented here suggests that there is cause for guarded optimism regarding the ability of many large African animals to cope with climate change. However, the long-term survival of these species is still dependent on careful management and the reduction of other stressors, many of which are anthropogenic in nature. We salute the hard-working staff of Africa's parks, natural areas and game ranches, and thank them for their efforts to integrate information about climate change into their management strategies and conservation activities for Africa's wonderful megafauna.

Photo by: Martha Surridge

AFRICAN ELEPHANT *Loxodonta africana* (Blumenbach)

Photo by: Martha Surridge

The African elephant is the world's largest land mammal and a member of the Big Five group of African wildlife species. Elephants were once widely distributed throughout sub-Saharan Africa (Kingdon 1997). Even though the species is still widespread, the current distribution is much patchier (Blanc 2008). Although declines have been noted in central and western African populations, substantial populations still exist in southern and eastern Africa. These latter populations continue to increase at a rate of approximately 4% per year (Blanc 2008). The African elephant has traditionally been divided into two subspecies, the African Savannah Elephant *Loxodonta africana africana* and the African Forest Elephant *Loxondonta africana cyclotis*, but recent DNA analysis suggests that these two forms are actually separate species (Rohland et al. 2010). However, this proposed reclassification has yet to be fully accepted by conservation authorities (e.g., Blanc 2008). The species as a whole is ranked as "Vulnerable" by the International Union for Conservation of Nature (IUCN) (Blanc 2008) although individual population segments are ranked as "Endangered" (central Africa), "Vulnerable" (western Africa, eastern Africa) and "Least Concern" (southern Africa).

ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

Water requirements – The African elephant is a water-dependent species, with requirements of 150 to 300 liters of water per animal per day for drinking, with additional amounts required for bathing (Du Toit 2002a,b; Garai 2005). As might be expected, acquisition of water forms a significant part of the daily activity for the species, although elephants in wet areas may go for three days without drinking (Spinage 1994). Water also plays an important role in many aspects of elephant behavior, including communal watering, group or individual play, and communal traveling between water sources. Herds of elephants will walk considerable distances (30 to 50 km or more) in search of water (Spinage 1994; Garai 2005). Elephants readily dig for water in dry riverbeds if surface water is not available (Garai 2005).

Sensitivity to heat – Elephants are heat-sensitive animals and individual elephants are susceptible to heat stress as well as sunburn (Garai 2005). An increase in body temperature of 1 to 2°C is considered a significant fever (Du Toit 2002b). Elephants manage their body temperature through a variety of means, including physiological (heat dissipation through their ears) as well as behavioral (mud baths, water baths, spraying of water through the trunk onto the body, and seeking shade; Spinage 1994; Garai 2005).

Sensitivity to drought – Drought has caused significant mortality in elephant populations in historic times, including well-studied incidents in Kenya's Tsavo National Park from 1960 to 1961 and from 1970 to 1975 (Spinage 1994). Drought also inhibits conception in female elephants (Spinage 1994).

Reproductive biology – Reproduction in African elephants is closely associated with seasonal climate conditions, with birth peaks coinciding with rainfall peaks (Du Toit 2002b). Drought conditions inhibit conception in female elephants (Spinage 1994). Changes to seasonal rainfall cycles could have effects on the reproductive biology of African elephants.

Intraspecific interactions – Under drought conditions, elephants will crowd the remaining water sources, leading to intraspecific fighting which may result in injuries such as tusk breakage (Spinage 1994).

Disease – Elephants are sensitive to a wide range of diseases, including: anthrax, trypanosomiasis, encephalo-myocarditis, salmonellosis, endotheliotropic herpes, foot-and-mouth disease and floppy trunk disease (Du Toit 2002b; Garai 2005), many of which are exacerbated by drought or heat stress.

Human Interactions – Human-wildlife conflict poses a significant threat to conservation efforts (Muruthi 2005). Poaching, crop raiding, water use and other conflicts with humans will increase as food and water resources are reduced due to climate change.

ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

Broad current distribution – Although the current range of the species has been substantially reduced from its maximum historic extent, the African elephant remains widely distributed throughout sub-Saharan Africa (Kingdon 1997). Across the range of the species, populations of African elephants have been exposed to considerable variation in temperature and precipitation regimes as well as elevational gradients and vegetation communities.

High population growth rate – Populations of African elephants in southern and eastern Africa are currently growing at an annual rate of approximately 4% per year (Blanc 2008).

Food – Elephants will feed on a wide range of plant materials, including: grasses, forbs, aquatic plans, leaves and twigs of trees, fruit, bark, roots and pith (Sukumar 2003; Garai 2005). Individual populations will often show preferences for particular plant species during particular seasons, but as many as 173 plant species may be consumed by a single population of elephants over the course of a year (Sukumar 2003).

Translocation and game ranching methods developed – Southern African wildlife biologists have developed methods for the translocation and long-term maintenance of individuals and herds of African elephants in game ranch conditions (Du Toit 2002b). Herds of animals have been successfully maintained in captivity and under game ranch conditions for many years (Du Toit 2002b; Garai 2005).

POTENTIAL EXPOSURE

The broad distribution of the African elephant across much of sub-Saharan Africa means that the species will inevitably be exposed to a variety of changes in future climate. In general, the species will experience warmer and drier conditions than at present, except for populations in central and eastern Africa which are expected to experience wetter conditions (precipitation changes by up to +7%; Boko et al. 2007). Populations in the central plateau of South Africa are likewise expected to experience greater precipitation from convective weather systems in summer (Boko et al. 2007).

ADAPTATION STRATEGIES

Provide Water – Given the importance of water to African elephant biology and behavior, ensuring the continued presence of surface water is an important climate adaptation strategy for this species. Artificial water sources (boreholes and tanks) may need to be provided in areas where surface water is no longer readily available. According to Du Toit (2002a), artificial watering sources are preferred by African elephants. However, some problem elephants may damage windmills and waterholes (Du Toit 2002c). In addition, it should be noted that water provision can create artificially high densities and concentrations of elephants and this can change the ecosystem in ways that disadvantage other species (Gaylard et al 2003).

Managing Other Stressors – At the present time, populations of African elephants continue to decline outside southern and eastern Africa (Blanc 2008), largely due to poaching, habitat loss, and habitat fragmentation. Reducing the effects of these stressors will help ensure that these populations have the capacity and opportunity to adapt to the effects of climate change.

Habitat Protection and Landscape Heterogeneity – Maintaining the opportunity for elephants to move across large landscapes offers them a better chance of adapting to a changing environment.

AFRICAN LION *Panthera leo* (Linnaeus)

The African Lion is the largest member of the cat family in Africa and one of the Big Five wildlife species. Lions once ranged widely from the Cape of Good Hope to southern Europe and western India, but the species' geographic range has shrunk considerably during historic times. Populations in Europe were extirpated approximately 2,000 years ago, most of the Asian populations were extirpated over the past 150 years, and those in northern Africa survived until the 1940s (Nowell and Packer 2008). Population declines in sub-Saharan Africa have continued in recent decades, driven by habitat loss, problem animal control, and trophy hunting (Nowell and Packer 2008; Whitman et al. 2007; Packer et al. 2009, 2011). The species is currently listed as "Vulnerable" by the IUCN (Nowell and Packer 2008). At present the species is divided into two subspecies, only one of which (*P. leo leo*) occurs in Africa (Skinner and Chimimba 2005).

Photo by: Martha Surridge

ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

Disease – Lions are susceptible to many common wildlife diseases and pathogens, including: anthrax, canine distemper, feline immunodeficiency virus and trypanosomiasis (Schaller 1972; Skinner and Chimimba 2005). Some of these diseases (e.g., anthrax) may be exacerbated by climate change (Prins 1996). Climate change may also increase the likelihood of lethal co-infections from multiple disease agents. Munson et al. (2008) have described a co-infection scenario for lion populations in the Serengeti and Ngorongoro Crater which involves *Babesia* hematoparasites and canine distemper virus. Extreme drought events triggered Cape buffalo die-offs that led buffalo ticks (which transmit *Babesia*) to seek new hosts, including lions. The combined presence of *Babesia* and canine distemper virus resulted in increased lion deaths in 1994 and 2001.

Population Decline – Extirpations of lion populations have been well documented (Skinner and Chimimba 2005; IUCN 2008) and the species has continued to decline throughout much of its remaining range, due to habitat loss, control of problem animals, and trophy hunting (Packer et al. 2009, 2011). Populations outside protected areas are especially at risk and conflicts with humans are expected to increase (Whitman et al. 2007; Packer et al. 2009, 2011). Reductions in population size and geographic range may limit the ability of lion populations to respond to climate change. Reductions in population size may result in the reduction of genetic variation which in turn limits the species' ability to evolve responses to climate change. Reductions in geographic range may limit the ability of lion populations to shift geographically in response to changing climatic conditions.

ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

Water requirements – Compared with the non-feline members of the Big Five (particularly African elephants and the two rhinoceros species), lions are quite resilient when it comes to daily water requirements. Although lions will drink readily when water is available, they can go for days without drinking under drought conditions (Skinner and Chimimba 2005). Under extreme climate conditions, lions also have the capacity to obtain the water needed for normal metabolic function from their prey items (Skinner and Chimimba 2005).

Food – Lions are predators and consume a very broad spectrum of animal species (Schaller 1972; Viljoen 2002; Skinner and Chimimba 2005). The preferred prey species is usually whatever potential food item is most abundant at the time (Skinner and Chimimba 2005). This flexibility suggests that lions will probably exhibit resilience to changes in the populations of prey species resulting from climate change.

Heat Tolerance – Lions are highly tolerant of direct sunlight and are often observed lying in the sun even when shade is available (Skinner and Chimimba 2005). Under extreme temperature conditions, lions pant and will seek available shade (Schaller 1972).

Subdermal body temperature fluctuates dramatically over the course of a day, by as much as 3°C in a female individual measured by Schaller (1972). This flexibility with regards to temperature suggests that direct heat effects from climate change are less likely to pose significant issues for lions, in comparison with other large mammal species such as African elephant and white rhinoceros.

Broad Current Distribution – Even though lion populations and the area occupied by lions have declined significantly since historic times, the species still occurs across much of sub-Saharan Africa (Kingdon 1997). Across the range of the species, populations of lions have been exposed to considerable variation in temperature and precipitation regimes as well as elevational gradients and vegetation communities (Skinner and Chimimba 2005) which suggests that the species may be fairly tolerant of climatic fluctuations.

Translocation and game ranching methods developed – Southern African wildlife biologists have developed methods for the translocation and long-term maintenance of individual lions, as well as groups of lions under game ranch conditions (Viljoen 2002). There is also a long history of maintenance of individuals and groups of lions in captivity (Schaller 1972).

POTENTIAL EXPOSURE

The broad distribution of lions across much of sub-Saharan Africa means that the species will inevitably be exposed to a variety of changes in future climate. In general, the species will experience warmer and drier conditions than at present, except for populations in central and eastern Africa which are expected to experience wetter conditions (precipitation changes by up to +7%; Boko et al. 2007). Populations in the central plateau of South Africa are likewise expected to experience greater precipitation from convective weather systems in summer (Boko et al. 2007).

ADAPTATION STRATEGIES

Managing Other Stressors – At present, populations of lions continue to decline throughout the species' range, largely due to habitat loss, problem animal removal and trophy hunting (Nowell and Packer 2008; Whitman et al. 2007; Packer et al. 2009, 2011). Reducing the effects of these stressors on existing lion populations will help ensure that these populations have the capacity and opportunity to adapt to the effects of climate change.

Photo by: Martha Surridge

Cape Buffalo *Syncerus caffer* (Sparrman)

The Cape or African buffalo is one of the Big Five African wildlife species and occurs throughout much of sub-Saharan Africa. Populations of this species have declined in certain parts of its range while other populations remain quite large. The species is currently ranked "Least Concern" by the IUCN, with over 900,000 extant individuals, although three quarters of these animals occur within protected areas (IUCN 2008g). Meat hunting and destruction of habitat are responsible for continuing declines of populations of this species outside of protected areas, while rinderpest continues to be a significant problem for certain populations (IUCN 2008g). Taxonomists have not arrived at a consensus regarding subspecific taxonomy of Cape buffalo, although three or four subspecies are usually recognized (IUCN 2008g).

Photo by: Martha Surridge

Elements of vulnerability to climate change

Water requirements – The Cape buffalo is a water-dependent species, requiring 30 to 40 liters of water per animal per day (Du Toit 2005a). Natural water sources are preferred (Du Toit 2002). Drinking is often combined with grazing because Cape buffalo will feed preferentially on grasses in the vicinity of established water sources (Du Toit 2002, 2005a). Given these substantial water requirements, reductions in surface water availability would likely negatively impact this species.

Sensitivity to heat – Direct sunlight on the dark coat of the Cape buffalo can cause subcutaneous body temperature to rise by as much 5°C (Du Toit 2005a). Such temperature increases can be prevented or moderated through physiological mechanisms such as sweating, or through behavioral mechanisms such as mud baths and resting in shady areas (Du Toit 2002, 2005a). There may be trade-offs between food, water and shade; Sinclair (1977) notes that Cape buffalo will remain in areas with suitable food and water resources even though the individual animals may be experiencing heat stress. Du Toit (2005a) notes that Cape buffalo will graze mainly at night in hot weather in order to reduce activity during the times of peak temperatures. Increases in temperature regimes have the potential to adversely affect Cape buffalo.

Sensitivity to drought – At least one historical large-scale mortality event in this species has been tentatively associated with a period of extreme drought (Prins 1986). Physical effects of malnutrition have been observed in individual animals under drought conditions (Mloszewski 1983); and Du Toit (2005a) recommends providing supplemental forage for captive Cape buffalo experiencing drought.

Food – Cape buffalo are primarily grazers but will also feed on forbs and shrubs (Du Toit 2005a). Seasonal feeding patterns are evident, with grasses forming the preferred forage during the dry season and a mix of grasses, forbs, shrubs and evergreen trees during the wet season (Sinclair 1977; Du Toit 2005a). The preferred grass species are high in protein content and carbohydrates (Prins 2005). Food sources near permanent water appear to be preferred (Du Toit 2002, 2005a). Reductions in surface water or changes in seasonal rainfall patterns could potentially lead to changes in available forage for the species.

Reproductive biology – Reproduction in Cape buffalo is strongly seasonal, with ovulation and oestrus peaking during the rainy season when high-quality browse is readily available (although some females may ovulate during the dry season; Prins 1996; Du Toit 2005a). This timing ensures that calving occurs during the subsequent rainy season, when females are at peak physiological condition (Prins 1996). Changes in the timing, frequency and intensity of seasonal rains could have effects on Cape buffalo reproductive biology.

Disease – Cape buffalo are susceptible to multiple wildlife diseases, including: rinderpest, brucellosis, bovine tuberculosis and anthrax. They also serve as carriers of foot-and-mouth disease and corridor disease to domestic livestock (Prins 1996; Du Toit 2005a). Several of these diseases are exacerbated or show peak activity under dry season conditions (Prins 1996).

Genetic bottlenecks – Populations of Cape buffalo experienced a significant genetic bottleneck during the rinderpest outbreak of the late 19^{th} and early 20^{th} century (Sinclair 1977; Prins 1996) when populations dropped as low as 20 individuals in the Kruger National Park (Stevenson-Hamilton 1911).

ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

Broad current distribution – Cape buffalo are widely distributed across sub-Saharan Africa (IUCN 2008g) and populations of the species have been exposed to a wide range of temperature and precipitation regimes as well as elevational gradients and vegetation communities.

Large current population size – The current population of Cape buffalo is estimated at approximately 900,000 individuals (IUCN 2008g).

Resiliency to disease – Cape buffalo populations have shown remarkable resilience to disease in historical times. Although rinderpest caused significant population declines in Cape buffalo populations during the late nineteenth and early 20th century, populations have rebounded significantly throughout its range (Sinclair 1977; Prins 1996).

Translocation and game ranching methods developed – Southern African wildlife biologists have developed methods for the translocation and long-term maintenance of individuals as well as herds of Cape buffalo in game ranch conditions (Du Toit 2002). Herds of animals have been successfully maintained in captivity and under game ranch conditions for many years (Du Toit 2002, 2005a).

POTENTIAL EXPOSURE

The broad distribution of Cape buffalo across much of sub-Saharan Africa means that the species will inevitably be exposed to a variety of changes in future climate. In general, the species will experience warmer and drier conditions than at present, except for populations in central and eastern Africa which are expected to experience wetter conditions (precipitation changes by up to +7%; Boko et al. 2007). Populations in the central plateau of South Africa are likewise expected to experience greater precipitation from convective weather systems in summer (Boko et al. 2007).

ADAPTATION STRATEGIES

Provide Water – Given the importance of water to Cape buffalo biology and behavior, ensuring the continued presence of surface water is an important climate adaptation strategy for this species. Artificial water sources (boreholes and tanks) may need to be provided in areas where surface water is no longer readily available.

Maintain Habitat Connectivity – Maintenance of landscape connectivity is an important conservation and management strategy for Cape buffalo, particularly in areas where herds move seasonally.

LEOPARD *Panthera pardus* (Linnaeus)

Photo by: Jonathan Mawdsley

The leopard is the largest spotted cat in Africa and a member of the Big Five group of animal species. Highly adaptable ambush predators with broad dietary tolerances, leopards formerly occurred throughout the continent of Africa as well as southern and eastern Asia (Skinner and Chimimba 2005). However, the species has experienced declines in large portions of its historic range as a result of hunting, predator control, habitat loss and habitat fragmentation (Henschel et al. 2008). The subspecific taxonomy of African leopards has been a subject of considerable debate, with some authors recognizing as many as thirteen subspecies and others as few as one (Myers 1976; Skinner and Chimimba 2005). Recent genetic analyses strongly suggest that all African leopards belong to the nominate subspecies *P. pardus pardus* (Miththapala et al. 1995; Uphyrkina et al. 2001). The species as a whole is listed as "Near Threatened" by the IUCN (Henschel et al. 2008) due to the significant declines observed in northern Africa and Asia.

ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

Disease – Leopards are susceptible to a number of wildlife diseases, including: anthrax, distemper, enteritis and rabies (Bailey 2005). Some of these diseases (e.g., anthrax) may be exacerbated by climate change (Prins 1996).

Population Decline – The decline of leopard populations across the range of the species is well documented (Henschel et al. 2008). Although leopard populations in sub-Saharan Africa have not declined to the extent seen in northern Africa and Asia, populations are patchy in many areas and the species occupies only 63% of its historic range south of the Sahara (Ray et al. 2005; Henschel et al. 2008). Reductions in population size and geographic range may limit the ability of leopard populations to respond to climate change. A population decrease may result in the reduction of genetic variation which in turn limits the species' ability to evolve responses to climate change. Constriction of the species' geographic range may limit the ability of leopard populations to shift geographically in response to changing climatic conditions.

ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

Food – Leopards are capable of killing and eating a very large number of prey species, primarily mammals under 70 kg in size (including small mammals such as hares and rodents), but also birds, insects and reptiles (Skinner and Chimimba 2005). Individual leopards may exhibit prey preferences but will readily consume other prey if the opportunity arises (Skinner and Chimimba 2005). This versatility in prey utilization suggests that the leopard would be relatively unaffected by changes in the relative abundance of individual prey species which might occur as a result of climate change.

Water – Leopards are able to obtain sufficient moisture from prey and are thus somewhat independent of water sources (Bailey 2005; Skinner and Chimimba 2005). Nevertheless, leopards will drink when they have the chance (Skinner and Chimimba 2005).

Broad Current Distribution – Despite declines, the leopard remains broadly distributed across sub-Saharan Africa and exhibits extremely broad habitat tolerances; leopards occur from sea level to over 2,000 meters and in areas with annual rainfall ranging from 100 to 1,200 mm (Myers 1976; Skinner and Chimimba 2005). Across the range of the species, populations of leopards have been exposed to considerable variation in temperature and precipitation regimes as well as elevational gradients and vegetation communities (Skinner and Chimimba 2005); this suggests that the species may be fairly tolerant of climatic fluctuations.

POTENTIAL EXPOSURE

The broad distribution of the leopard across sub-Saharan Africa means that the species will inevitably be exposed to a variety of changes in future climate conditions. In general, the species will experience warmer and drier conditions than at present, except for populations in central and eastern Africa which are expected to experience wetter conditions (precipitation changes by up to +7%; Boko et al. 2007). Populations in the central plateau of South Africa are likewise expected to experience greater precipitation from convective weather systems in summer (Boko et al. 2007).

ADAPTATION STRATEGIES

Managing Other Stressors – The historic and recent declines in leopard populations are being driven primarily by a combination of habitat loss, habitat fragmentation, hunting and problem animal control (Henschel et al. 2008). To date, climate change has not been implicated in leopard population declines, although the potential certainly exists for climate change to exacerbate known vulnerabilities such as disease, as it has occurred in lions (Munson et al. 2008). Reducing the effects of these other, mostly anthropogenic, stressors on leopard populations should help provide the species with greater flexibility to adapt to changing climatic conditions.

Photo by: Martha Surridge

Black Rhinoceros *Diceros bicornis* (Linnaeus)

Photo by: Harald Zimmer via Wikimedia Commons

The black rhinoceros was once widely distributed across eastern and southern Africa, with populations extending to the northwest into Nigeria and as far north as Sudan (Hillman-Smith and Groves 1994). The current range of the species is now greatly reduced with 96% of the existing populations in just four countries (South Africa, Namibia, Zimbabwe and Kenya; Emslie 2011a). The most recent classification divides the black rhinoceros into four subspecies, one of which (the west African black rhinoceros) is now thought to be extinct (Emslie 2011b). Total population numbers across all subspecies declined by 96% between 1970 and 1992 (Emslie and Brooks 1999) and the species is currently listed as "Critically Endangered" by the IUCN (Emslie 2011a). Certain populations in South Africa and Namibia are increasing (Emslie 2011a) but the total number of individuals remains small with just 4,880 individuals across all three surviving subspecies. As with the white rhinoceros, intensive poaching for their horns continues to threaten all three black rhinoceros subspecies (Emslie 2011a).

Elements of vulnerability to climate change

Water requirements – The black rhinoceros is considered water-dependent (Du Toit 2005b). However, desert populations may be semi-independent from surface water sources. The daily water requirements of the black rhinoceros are less than 50% of those of the white rhinoceros but are still substantial, averaging 35 liters of water per animal per day (Du Toit 2002a). Artificial watering points are preferred (Du Toit 2002a) and the species also uses mud baths for removal of parasites and thermoregulation (Schenkel and Schenkel-Hulliger 1969; Du Toit 2005b). When surface water is not available the black rhinoceros will dig for water in dry sandy river beds (Du Toit 2005b). Availability of surface water is one of the criteria by which male black rhinoceros select a territory (Du Toit 2005b). Reductions in available water, whether caused by changes in temperature regimes and/or precipitation patterns, have the potential to significantly affect individuals and populations of black rhinoceros.

Sensitivity to heat – Because the black rhinoceros are sensitive to heat, they use mud baths for thermoregulation and also rest in the shade during the heat of the day (Schenkel and Schenkel-Hulliger 1969; Du Toit 2005b).

Sensitivity to drought – Large-scale deaths of black rhinoceros have occurred under drought conditions in Kenya; however, populations in Namibia are apparently more resistant to drought (Du Toit 2005b).

Food – The black rhinoceros is a browser and feeds exclusively on small shrubs and forbs (Hillman-Smith and Groves 1994), with preferences for *Dichrostachys cinerea*, *Spirostachys africana*, and species of the genera *Acacia*, *Grewia*, *Croton*, *Euphorbia*, and *Combretum* (Du Toit 2005b). Climate change could potentially alter the extent of woody vegetation relative to grasses in African savannahs and thereby either increase or reduce the amount of foraging habitat available for this species. Climate change may also increase fire frequency in some areas of this species' range, leading to increased tree mortality and reductions in available forage.

Reproductive biology – As with white rhinoceros, reproduction in black rhinoceros appears to be correlated at least in part with the seasonal rain cycle, with both oestrus and birth peaks associated with periods of seasonal rainfall (Du Toit 2005b). Although oestrus is not entirely seasonally dependent (Pienaar and Du Toit 2002), changes to seasonal rain patterns could alter the reproductive biology of this species. As noted above, the presence of permanent surface water is one of the criteria by which male black rhinoceros establish breeding territories (Du Toit 2005b).

Genetic bottlenecks – This species has arguably experienced a significant bottleneck event, with a 96% reduction in total population numbers between 1970 and 1992 (Emslie and Brooks 1999) and the complete extinction of one subspecies (Emslie 2011b).

Intraspecific Interactions – As with white rhinoceros, crowding of males at water holes under drought conditions leads to increased conflicts and mortality (Du Toit 2005b). Increased or intensified drought conditions would likely exacerbate these conflicts.

Disease – Black rhinoceros are susceptible to certain diseases that may be aggravated by climate change. Anthrax is a source of mortality in wild black rhinoceros (Du Toit 2005b) and outbreaks may be associated with drought conditions which increase wind erosion of soils and lead to increased spore release (Pienaar and Du Toit 2002). Parasitic dermatitis is a condition which commonly affects wild black rhinoceros; the lesions from this disease are largest in summer, leading to the common name of "summer sores" for the infection. Black rhinoceros are also susceptible to trypanosomiasis and tick-borne diseases such as babesiosis and theileriosis (Du Toit 2005b).

ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

Broad historic distribution – The four subspecies of black rhinoceros were widely distributed historically across southern, eastern and north-central Africa (Hillman-Smith and Groves 1994), exposing historic populations to a wide range of temperature and precipitation regimes as well as elevational gradients and vegetation communities.

Disease resistance – Neither the black nor white rhinoceroses are susceptible to rinderpest (Ansell 1969).

Translocation and game ranching methods developed – Southern African wildlife biologists have developed methods for the translocation and long-term maintenance of individual black rhinoceroses in game ranch conditions (Pienaar and Du Toit 2002). Animals have been successfully maintained in captivity and under game ranch conditions for many years (Du Toit 2005b).

POTENTIAL EXPOSURE

Models of climate change in southern Africa consistently suggest that extant populations of black rhinoceros in South Africa, Namibia, Zimbabwe and Kenya will be exposed to warmer temperatures and decreased rainfall, except for the central plateau of South Africa where summer precipitation is expected to increase (Boko 2007). Hulme et al. (2001) estimate that temperatures in the surviving range of the species will increase by 1.6 to 7.0°C by 2080, with precipitation decreasing by 0 to 12%.

ADAPTATION STRATEGIES

Provide Water – Given the importance of water to black rhinoceros biology and behavior, ensuring the continued presence of surface water is an important climate adaptation strategy for this species. Artificial water sources (boreholes and tanks) may need to be provided in areas where surface water is no longer readily available.

Managing Other Stressors – At the present time, poaching is a much greater threat to the survival of black rhinoceros than climate change (Emslie 2011a). Reducing the illegal harvest of black rhinoceros for the horn trade is clearly the most important conservation priority for all three remaining subspecies. Reducing the stress on black rhinoceros populations from poaching will help ensure that these populations have the capacity and opportunity to adapt to the effects of climate change.

WHITE RHINOCEROS *Ceratotherium simum* (Burchell)

Photo by: Jonathan Mawdsley

The white rhinoceros is the fourth largest land mammal, after the three species of elephants. Most authors recognize two subspecies, the Northern White Rhinoceros and the Southern White Rhinoceros (Groves 1972; Kingdon 1997), although Groves et al. (2010) have recently argued that these two forms should be considered separate species. The species as a whole is considered "Near Threatened" by the IUCN (Emslie 2011c). The northern subspecies is currently considered to be "Critically Endangered," with very few surviving individuals in either captivity or in the wild (Emslie 2011c). The southern subspecies is now considered "Near Threatened" (Emslie 2011c) but survived a significant historical population bottleneck in the late 19^{th} and early 20^{th} century, when the total population size was reduced to no more than 180 individuals (Foster 1960) and possibly as low as six (Sidney 1965). However, as a result of extensive reintroduction efforts (Groves 1972; Emslie 2011c) the southern subspecies subsequently rebounded to a population of over 17,000 individuals as of 2007 (Emslie 2011c). Intense poaching activities and illegal harvest of rhinoceros horn continues to threaten both subspecies, even in conservation areas, game ranches and national parks (Emslie 2011c).

ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

Water Requirements – White rhinoceroses are considered water-dependent animals, requiring up to 80 liters of water per day (Groves 1972). Individual animals will drink daily if water is available, but can go without water for up to four days (Pienaar and Du Toit 2002). Shallow areas of standing water are commonly used for wallowing and mud baths, which perform a thermoregulatory function and help to reduce external parasites (Pienaar and Du Toit 2002). Reductions in available surface water, whether caused by changes in temperature regimes and/or precipitation patterns, have the potential to significantly affect individuals and populations of white rhinoceros.

Sensitivity to heat – White rhinoceros will rest in the shade, mud baths or pans during the heat of the day (Pienaar and Du Toit 2002). Foraging activities generally occur in the early morning, late afternoon and evening, when temperatures are not as severe (Pienaar and Du Toit 2002).

Sensitivity to Drought – Pienaar and Du Toit (2002) note that extensive mortality of this species can occur during periods of extended drought. During times of drought, individual animals will attempt to move to other permanent water sources. Even when such water sources are located, the increased concentration of individual animals around water holes can lead to increases in territorial conflicts and animal mortality.

Food – The white rhinoceros is a grazer and feeds exclusively on grasses (Groves 1972), with local and regional preferences for particular grass species (Player and Feely 1960; Sidney 1965). Climate change could potentially alter the extent of grasses relative to woody species and thereby either increase or reduce the amount of foraging habitat available for this species. Climate change may also increase fire frequency in some areas of this species' range, leading to increased tree mortality and expansion of grasslands.

Reproductive Biology – According to Pienaar and Du Toit (2002), oestrus in female white rhinoceros is stimulated by the presence of new green grass following seasonal rains, which leads to a birth peak 16 months later. Although oestrus is not entirely seasonally dependent (Pienaar and Du Toit 2002), changes to seasonal rain patterns could alter the reproductive biology of this species.

Genetic bottlenecks – Both subspecies of white rhinoceros have experienced significant population reductions which could lead to decreased genetic diversity; the northern subspecies is presently in the midst of a bottleneck event and the southern subspecies experienced a significant population constriction in the late 19th and early 20th century (Groves 1972; Emslie 2011c).

Intraspecific Interactions – Pienaar and Du Toit (2002) note that fighting between male white rhinoceroses in Kruger National Park increases towards the end of the dry season when water availability is limited. Fighting is thought to be responsible for 50% of the mortality in adult male white rhinoceroses (Pienaar and Du Toit 2002).

Disease – White rhinoceros are susceptible to anthrax (Pienaar and Du Toit 2002). Drought conditions may accelerate the release of anthrax spores into the environment, as formerly stable soils become desiccated and are eroded by wind action.

ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

Broad historic distribution – Both subspecies of white rhinoceros were widely distributed historically across northern and southern Africa (Groves 1972), exposing historic populations to a wide range of temperature and precipitation regimes as well as elevational gradients and vegetation communities.

Resistance to disease – White rhinoceros are not susceptible to rinderpest; and blood parasites such as babesia, theileria, and trypanosoma can be found in the blood of white rhinoceros without the animals exhibiting signs of these diseases (Pienaar and Du Toit 2002).

Translocation and game ranching methods developed – Southern African wildlife biologists have developed methods for the translocation and long-term maintenance of individual white rhinoceroses in game ranch conditions (Pienaar and Du Toit 2002). Animals have been successfully maintained in captivity or game ranch conditions for many years (Groves 1972) and there is an active market in southern Africa for surplus animals to stock new areas (Bothma et al. 2002).

POTENTIAL EXPOSURE

Models of climate change in southern Africa suggest that extant populations of southern white rhinoceros will be exposed to warmer temperatures and changes in rainfall. Temperatures in the current extant range of this subspecies (Emslie 2011c) are projected to increase between 1.3 to 7.0°C by 2080 (Hulme et al. 2001). Precipitation in the western part of the species' range is expected to decrease by 0 to 26% (Hulme et al. 2001), while summer convective precipitation in the central and eastern plateau region of South Africa is expected to increase (Boko et al. 2007).

Models of climate change in north-central Africa suggest that the recent range of northern white rhinoceros (Emslie 2011c) will be exposed to warmer temperatures and increased rainfall. Temperatures in the recent geographic range of the species are projected to increase between 1.5 to 5.3°C, while precipitation in the same area is expected to increase by approximately 7% (Hulme et al. 2001; Boko et al. 2007).

ADAPTATION STRATEGIES

Provide Water – Given the importance of water to white rhinoceros biology and behavior, ensuring the continued presence of surface water is an important climate adaptation strategy for this species. Artificial water sources (boreholes and tanks) may need to be provided in areas where surface water is no longer readily available.

Managing Other Stressors – At the present time, poaching is a much greater threat to the survival of white rhinoceros than climate change (Emslie 2011c). Reducing the illegal harvest of white rhinoceros for the horn trade is clearly the most important conservation priority for both subspecies. Reducing the stress on white rhinoceros populations from poaching will help ensure that these populations have the capacity and opportunity to adapt to the effects of climate change.

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