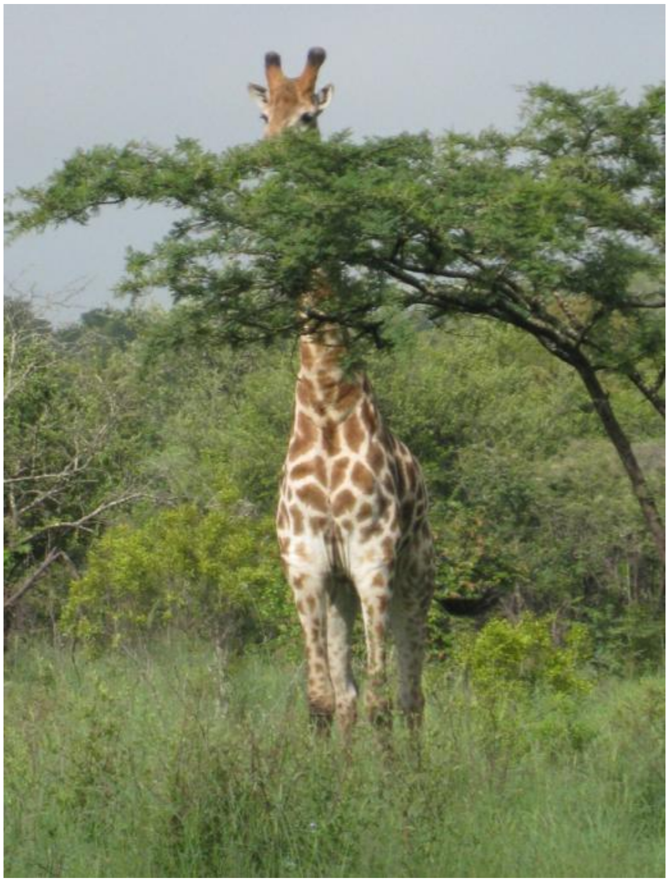

# Climate-change Vulnerabilities and Adaptation Strategies for Africa's Charismatic Megafauna

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## 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<br>40.0 | 2000<br>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<br>56.3 | 2001<br>2008 |
| Zambia | 72.8 | 3.6 | 2002 |
| Zimbabwe | 143.5 | 18.5<br>15.8 | 2000<br>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<br>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<br>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 21$^{st}$ 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<br>*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<br>2. Improve representation and replication within protected area networks<br>3. Manage and restore existing protected areas to maximize resilience<br>4. Design new natural areas and restoration sites to maximize resilience<br>5. Protect movement corridors and "stepping stones"<br>6. Manage and restore ecosystem function, rather than focusing on specific components (species, community assemblages)<br>7. Improve the matrix—increase landscape connectivity and permeability to species movement<br>8. Reduce non-climate stressors on natural areas and ecosystems |
| Species Conservation | 9. Focus conservation resources on species that might become extinct<br>10. Translocation or assisted dispersal of species<br>11. Establish captive populations of species that would otherwise go extinct<br>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:<br>a) how these programs will need to be modified to provide management-relevant information on the effects of climate change<br>b) what new monitoring systems will need to be established in order to address gaps in our knowledge of climate effects<br>14. Incorporate predicted climate change impacts into species and land management plans, programs and activities<br>15. Develop dynamic landscape conservation plans<br>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<br>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 19th and early 20th 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 19th and early 20th 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.

## **AFRICAN WILD DOG** *Lycaon pictus* (Temminck)

African wild dogs have unique markings of white, black and yellow blotches, which is why they are sometimes called painted dogs (Skinner and Chimimba 2005). The IUCN lists these medium-sized carnivores as "Endangered" (McNutt 2008). Wild dogs are found in a variety of habitats, including: short-grass plains, semi-desert, bushy savannas and upland forest (McNutt 2008). A century ago, wild dogs ranged widely across sub-Saharan Africa but they have since been extirpated from most of this area (Skinner and Chimimba 2005). According to recent estimates, there are between 3,000 to 5,500 free-ranging wild dogs left with the largest populations in southern Africa and the southern section of eastern Africa (McNutt 2008). Due to habitat fragmentation, human activities and disease the population of African wild dogs is still declining (McNutt 2008).

Photo by: Jonathan Mawdsley

### ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

**Range requirements** – African wild dogs require very large home ranges (McNutt 2008). For example, in South Africa's Kruger National Park, one pack uses 885 square km (Skinner and Chimimba 2005). The need for such an extensive area often leads wild dogs to roam beyond the boundaries of protected areas (Creel and Creel 1996). This wandering can be dangerous because nearby private ranchers are intolerant of wild dogs (Skinner and Chimimba 2005). It is human activities and the availability of prey that limit the distribution of wild dogs, not loss of any particular habitat type (McNutt 2008).

**Disease** – African wild dogs can fall victim to many diseases, including: rabies, distemper, canine parvovirus, anthrax and canine ehrlichiosis (Skinner and Chimimba 2005). After rabies and distemper decimated wild dog populations in the Serengeti, they were considered particularly sensitive and vulnerable to disease (Ginsberg et al. 1995; Kat et al. 1995; Alexander et al. 1993). However, data from outside of that region show that wild dogs are no more vulnerable to disease than they are to other factors, such as human activities and competition with other carnivores (Creel and Creel 2002). African wild dogs live in small populations and that does put them at risk of local extinctions from disease epidemics (Creel and Creel 2002). Domestic dogs are a source of disease and infections can be transmitted by typical pack social interactions (Kat et al. 1995; Creel and Creel 2002). Although an entire pack can easily become infected, wild dogs rarely interact with other packs and thus the infection will not spread further (Skinner and Chimimba 2005).

**Interspecific competition** – African wild dogs are generalist predators that usually hunt medium-sized antelope (McNutt 2008). A typical pack will kill at least three animals a day and the prey may weigh anywhere from 50 to 200 kg (Skinner and Chimimba 2005; McNutt 2008). Although their prey preference varies based on location, their overall diet is very similar to that of spotted hyena and overlaps with that of lions (Skinner and Chimimba 2005). Due to this competition, the presence of hyena and lion in an area is correlated to the density of wild dogs (Creel and Creel 1996). African wild dogs rarely scavenge food, but can lose their own kills to these larger carnivores and this is energetically costly (Skinner and Chimimba 2005). If a pack loses 25% of its food to other carnivores, then it must spend an extra nine hours hunting that day (Skinner and Chimimba 2005). Medium-sized hunting groups most efficiently balance the need for numbers to defend kills with the nutritional needs of each dog in the pack (Carbone et al. 1997). In addition, wild dogs may themselves become prey for hyena and, more commonly, lion (Creel and Creel 1996). Unlike larger carnivores, wild dog populations stay at low densities regardless of the conditions (Creel and Creel 2002).

**Small Populations** – African wild dogs have always lived at low population densities and that makes them exceptionally vulnerable to catastrophic events like disease epidemics (McNutt 2008). According to various simulations of ecological and demographic conditions, typical wild dog populations (less than 100 individuals) are at great risk of extinction in the next century (Creel and Creel

2002). Increasing population size reduces the risk; unfortunately, several factors limit the size of wild dog packs (Vucetich and Creel 1999). As mentioned earlier, the presence of hyena and lions depresses wild dog populations (Skinner and Chimimba 2005). Even when the competition is minimal, reproductive suppression puts a ceiling on pack size (Vucetich and Creel 1999). Those small populations that are in small habitat patches will be more vulnerable to human activities (IUCN 2011).

#### ELEMENTS OF RESILIENCE TO CLIMATE CHANGE

**Water independent** – Like other water-independent species, the African wild dog will drink water when it is available but does not require habitat with surface water (Skinner and Chimimba 2005).

**Heat tolerance** – Wild dogs hunt in the morning and evening to avoid the hottest hours of the day (Skinner and Chimimba 2005). When they are hunting, wild dogs are adapted to running for long periods in the heat without dehydrating; their body temperature can rise substantially to stay above the ambient temperature which prevents sweating (Marino 2008). This is vital given that wild dogs may have to run over 2 km at a pace of 66 km/hr before capturing their prey (Skinner and Chimimba 2005).

**Genetic distribution** – Within a pack, the gene pool is usually limited to the dominant animals because reproduction is suppressed in their subordinates (Skinner and Chimimba 2005). Dispersal allows both male and females to escape the reproductive suppression in their natal pack (Creel and Creel 1996). This dispersal of young to other packs has maintained high genetic variability on a large scale (Skinner and Chimimba 2005). In fact, wild dogs can travel as much as 139 to 250 km to join a new pack (Skinner and Chimimba 2005). Wild dogs do mate seasonally so that more prey will be available when pups are born (Skinner and Chimimba 2005).

**Living in packs** – African wild dogs live in packs with strong social bonds that are maintained through specific behaviors and vocalizations (Robbins 2000). By hunting as a pack they improve their success in capturing prey, can capture larger prey and reduce the length of the chase (Skinner and Chimimba 2005; Creel and Creel 1996; Woodroffe et al. 2007). According to one study, a wild dog pack hunted successfully 85% of the time (Estes and Goddard 1967). Not only do wild dogs cooperate in hunting, but they also share responsibility for caring for their young (McCreery and Robbins 2001). For the most part, only the dominant dogs in a pack reproduce (Spiering et al. 2010); nevertheless, all dogs within the pack help to feed and protect the pups (Malcolm and Marten 1982).

**Broad historic range** – Wild dogs used to range across the many habitats of sub-Saharan Africa, except for lowland rainforest and severe desert (McNutt 2008). Thus, the species has shown the adaptability to subsist under a wide range of conditions.

#### POTENTIAL EXPOSURE

African wild dogs exist in patches across all of sub-Saharan Africa which means that the species will be exposed to myriad effects of climate change. Models predict a significant decrease in the dry season precipitation for southern Africa; whereas, there will be an annual mean increase in eastern Africa (IPCC 2007). Temperatures will increase by 1.9 to 4.8°C in the south and 1.8 to 4.3°C in the east (IPCC 2007).

#### ADAPTATION STRATEGIES

**Population management and reintroduction** – Vulnerable groups of wild dogs may be assisted by active management of the entire metapopulation (Vucetich and Creel 1999; Lindsey et al. 2005). Over 300 wild dogs exist in captivity and there have been several successful reintroductions to reserves in South Africa (Skinner and Chimimba 2005). When establishing a new pack, it is important that captive-bred animals be mixed with those caught from the wild to increase their hunting success (McNutt 2008; Gusset et al. 2008).

**Disease prevention** – More research is needed to determine if and how wild dogs can be vaccinated to prevent rabies and distemper (McNutt 2008).

**Manage other stressors** – Future conflict between African wild dogs and humans is a paramount concern as their habitat becomes more fragmented (McNutt 2008). Wild dogs are legally protected in most areas but the lack of enforcement puts them at risk (IUCN 2011). For example, they may be persecuted by farmers even though wild dogs rarely kill livestock (Skinner and Chimimba 2005).

## **BONGO** *Tragelaphus eurycerus* (Ogilby)

Photo by: Greg Hume via Wikipedia Commons

The bongo is one of the largest and most magnificent African forest antelope species, with a glossy red-chestnut coat, black muzzle, and distinctive white spots and stripes. Both sexes have long, yellow-tipped, lyre-shaped horns on their heads (Ralls 1978). Bongos are largely nocturnal and highly elusive, making them a prize species for sport hunters as well as wildlife watchers (Hillman 1986; Klaus et al. 2000). They live in dense tropical rainforests in western and central Africa, particularly in dense areas of disturbed or early-successional forest (IUCN 2008). Most of the known populations are associated with lowland forests but Kenyan populations occur at higher elevations (2100 to 3000 meters; Ralls 1978). The species is currently divided into two subspecies, the lowland or western bongo *T. e. eurycerus*, and the mountain or eastern bongo *T. e. isaaci* (Thomas) (IUCN 2008). Both subspecies have declined in numbers in recent decades and the species is considered to be extirpated or likely to be extirpated from Benin, Togo and Uganda (IUCN 2008). The lowland or eastern subspecies is classified by the IUCN (2008) as "Near Threatened" while the mountain or eastern subspecies is classified as "Critically Endangered." The latter subspecies has experienced an extraordinary decline, with only 140 individuals surviving in the wild, compared with over 250 individuals of this subspecies living in zoos and conservation facilities (IUCN 2008).

### ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

**Water availability** – Bongos require permanent water sources (Nowak 1991); any decrease in the amount of available surface water within the species' habitat area as a result of climate change would presumably be detrimental to the bongo.

**Food** – Bongos are primarily browsers, although grass species are also occasionally eaten (Ralls 1978). Any changes to the forest landscape that reduced the amount of available browse would presumably have adverse impacts on the bongo populations.

**Genetic bottlenecks** – Both subspecies of bongo have experienced population declines and consequently may be at risk for loss of genetic diversity. Extirpations of bongo populations have been noted in Benin, Kenya, Togo and Uganda; and the western African populations are currently separated from the central African populations (IUCN 2008). The eastern or mountain subspecies has clearly experienced a significant recent bottleneck in its population size, with only 390 individuals remaining at the present time, 250 of which are in captivity (IUCN 2008). Genetic bottlenecks are thought to increase species' vulnerability to climate change, because reductions in the natural genetic variation of a species will also likely reduce the species' inherent ability to evolve responses to environmental stressors such as climate change.

**Disease** – Bongos are susceptible to a number of common wildlife diseases; concern has also been expressed about the possibility of disease transmission between domestic cattle and bongo populations in Kenya (IUCN 2008). Rinderpest is thought to have nearly extirpated the species in the late 19th century (Percival 1928). Any changes in climate which improved conditions for the spread of wildlife disease could adversely affect bongo populations.

**Illegal harvest** – Illegal harvest has been implicated in bongo extirpations in Kenya (Ralls 1978; IUCN 2008). The species is easily trapped with simple snares or hunted with dogs, and is currently under threat throughout its range by illegal harvest for bushmeat (IUCN2008). In contrast to illegal harvest, commercial hunting is very likely to prove a viable conservation strategy for protecting the species, especially in areas where the possibility of successful eco-tourism development is unlikely (IUCN 2008).

### ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

**Broad historic distribution** – Historically, the bongo was widely distributed across the lowland tropical forests of western and central Africa, with populations extending up to 4300 meters in the mountains of Kenya (Ralls 1978; IUCN 2008). This broad historic distribution suggests that the species has been exposed to a wide range of temperature and precipitation regimes. Such past exposure may help the species by enabling it to adapt physiologically to survive the current era of global climate change.

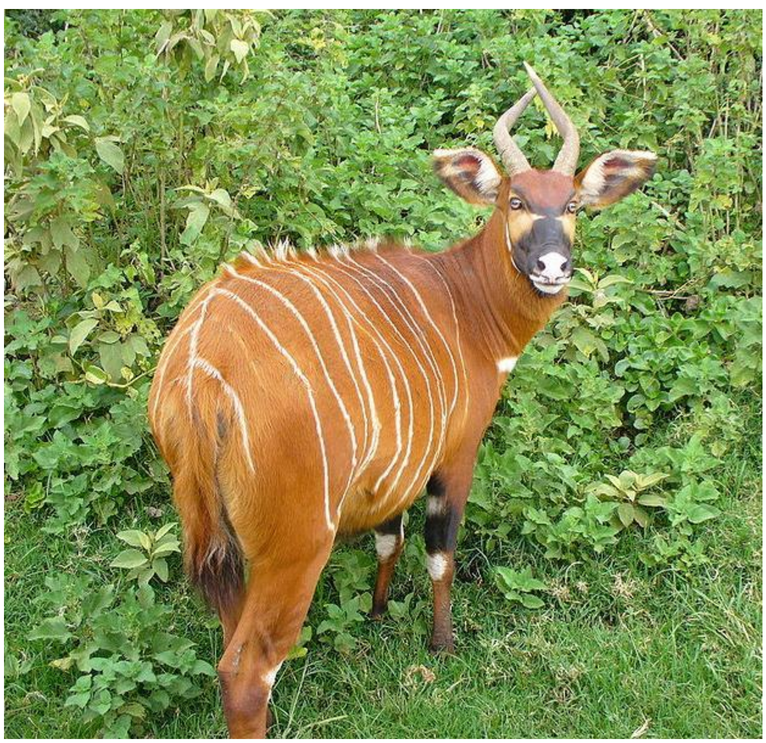
**Captive husbandry and game ranching methods developed** – Bongos have been maintained for multiple generations in captivity and the mountain or eastern subspecies survives primarily in zoos and other conservation facilities (IUCN 2008). Adult bongos have been imported into Texas for purposes of sport hunting; one such hunt advertised on the internet was priced at US$29,500 per animal harvested.

### POTENTIAL EXPOSURE

Projections of climate change in central and western Africa suggest that temperature change will be less pronounced in the equatorial regions than elsewhere on the continent, while precipitation levels will increase by as much as 7% above current levels (Boko et al. 2007). The precipitation increases projected by the IPCC for central Africa are in sharp contrast to the significant reductions expected elsewhere on the continent. Increases in precipitation could potentially benefit bongo populations if surface water becomes more widely available as a result.

### ADAPTATION STRATEGIES

**Reducing other stressors** – It is clear that illegal hunting and habitat loss are the two major drivers of current population declines in bongos (IUCN 2008). The bongo is one of the principal species harvested for bushmeat in central and western Africa (IUCN 2008); thus, any measures that actually decreased harvest of wild bushmeat would certainly benefit this species. Illegal harvest is thought to be the cause of recent extirpations of small remnant populations of the eastern subspecies of bongo in Kenya (IUCN 2008). Reductions in habitat loss and habitat fragmentation would also benefit the species. While bongos will utilize disturbed areas, particularly areas with dense, early-successional vegetation, the complete elimination of suitable habitat (as occurs with some commercial forestry operations) is clearly detrimental to the species (IUCN 2008). Reductions in these and other stressors have the potential to provide bongo populations with additional flexibility in responding to climate change.



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## **CHEETAH** *Acinonyx jubatus* (Von Schreber)

The cheetah is well known as the fastest animal on land; at its fastest it can run 105 km/hr (65 mph) to chase its prey (Skinner and Chimimba 2005). However, more typically cheetah run 85 km/hr (52mph) and can only maintain their top speed for up to 300 m (Skinner and Chimimba 2005). The IUCN lists cheetah as "Vulnerable;" there are about 7,500 cheetah and this population is at least 30% less than in the 1970s (Durant 2008; Myers 1975). Cheetah are found predominantly in eastern and southern Africa and occupy a tiny fraction of their historical range (Durant 2008). Only a small portion of the cheetah population inhabits protected areas, where they must compete with lions and hyena (Durant 2008; Skinner and Chimimba 2005). On private land, cheetah are captured or killed when blamed, often erroneously, for preying on livestock (Durant 2008).

Photo by: Martha Surridge

#### **ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE**

**Genetic bottleneck** – After their speed, cheetah are unfortunately well known for a serious lack of genetic diversity (O'Brien et al. 1983). Cheetah have undergone at least two genetic bottlenecks in the past, one within the last century and the other approximately 10,000 years ago (O'Brien et al. 1987). The subsequent inbreeding resulted in a smaller gene pool that makes the species more vulnerable to the threat of climate change. Cheetah are particularly sensitive to changes in their environment; a small change can bring instability to a population (Myers 1975). The conservation of cheetah depends on a large metapopulation and cross-pollination across subpopulations (Lindsey et al. 2011; Durant 2008).

**Large range requirements** – In order to recover their former numbers, cheetah will need a connected habitat that allows for the flow of genes across subpopulations (Durant 2007). Cheetah exist at lower densities than other large carnivores; thus, they require very large home ranges (Durant 2007; Skinner and Chimimba 2005). As cheetah habitat is lost it will become more difficult to find sufficiently large areas for conservation and reintroduction projects (Lindsey et al. 2011).

**Thermoregulation** – During the heat of midday, cheetah rest in the shade on elevated ground (Skinner and Chimimba 2005). But this is not sufficient for a cheetah to cope with increases in its body temperature (up to 60-times greater than when at rest) caused by the vigorous pursuit of prey (Taylor and Rowntree 1973). Although cheetah have the capacity for large changes in their respiratory rate, they still require significant recovery time after a chase and may seek shade for 30 minutes after an unsuccessful hunt (Eaton 1982; Marino 2008). When it does catch its prey, the exhausted cheetah has little time to recover if it is to feed before other carnivores steal its catch (Skinner and Chimimba 2005; Durant 2008). Cheetah rely on a heat-storage strategy for thermoregulation while they sprint; only after the sprint do their evaporative heat-loss mechanisms kick in to dissipate the excess body heat (Taylor and Rowntree 1973). If a cheetah does not break off its pursuit after 200 m, the increase in its body heat will become intolerable (Marino 2008). Lying down compresses the rib cage and increases recovery time (Eaton 1982). Cheetah will not run once the air temperature reaches 50°C (Talyor and Rowntree 1973).

**Reproductive biology** – A lack of genetic diversity contributes to the poor reproductive success of cheetah in captivity and in the wild (O'Brien 1985). Not only do male cheetahs have a low concentration of spermatozoa, but also nearly 80% of those gametes are morphologically abnormal (O'Brien et al. 1987). There is no specific breeding season for cheetah, but they tend to give birth at the start of the wet season from March to June (Skinner and Chimimba 2005; Eaton 1982). During the first few weeks of life, over 90% of cheetah cubs are killed by lions and other carnivores (Hayward et al. 2006). As a result, usually only two cubs survive and over their entire lifetimes females only produce 1.7 cubs to independence (Skinner and Chimimba 2005). It has also been suggested that the high degree of juvenile mortality is a consequence of the species' genetic uniformity (O'Brien 1985).

**Disease** – Their limited genetic diversity also makes cheetahs very vulnerable to disease (Munson et al. 2005; O'Brien et al. 1985). Cheetahs in captivity have fallen victim to feline distemper (Eaton 1982). Captive wild-caught cheetahs have suffered from feline infectious peritonitis (Meltzer 1993).

### ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

**Water independence** – Cheetah are so well adapted to arid environments that they do not require surface water in their habitat; instead, they get moisture from their prey and occasionally from tsama melons (Skinner and Chimimba 2005). When water is available, cheetah will drink but they have been observed travelling 80 km between drinks (Skinner and Chimimba 2005).

**Diet** – Cheetah are best adapted to capture medium-sized prey, such as blesbok, impala and springbok (Hayward et al. 2006). The season and vegetation cover affect hunting success (Houser et al. 2009). Conditions during the wet season are more difficult because cheetah are more visible in green grass and their prey are more spread out (Eaton 1982). Therefore, prolonged dry seasons due to climate change may, paradoxically, put cheetah at an advantage when hunting.

**Historic distribution** – In the past, cheetah were distributed throughout Africa but have lost 76% of their historic range (Skinner and Chimimba 2005; Durant 2008). Their broad historic range exposed cheetah to a variety of temperature and precipitation regimes as well as elevational gradients and vegetation communities. Today, the cheetah continues to show its tolerance of disparate habitats. Cheetah habitat can range from near desert to open grassland to thick bush (Eaton 1982). They have also been reported on mountains in Kenya and the central Sahara (Durant 2008).

### POTENTIAL EXPOSURE

Cheetah are predominantly found in Kenya, Tanzania, Namibia and Botswana (Skinner and Chimimba 2005). They will encounter a hotter climate with some more rainfall in the east, where models predict a temperature increase of 1.8 to 4.3°C (IPCC 2007). In the south, cheetah will see significantly drier conditions; the IPCC (2007) predicts an annual change in precipitation of -12% to 6+%. This decrease will be as much as -43% to +3% during the dry months; the frequency of extreme dry seasons will increase from 20 to 23% (IPCC 2007). Average annual temperatures in southern Africa will increase by 1.9 to 4.8°C (IPCC 2007).

### ADAPTATION STRATEGIES

**Captive breeding and reintroduction** – There have been great advances, including artificial insemination, in the captive breeding of cheetahs in zoos. Nevertheless, the cheetah remains a difficult species to breed and is vulnerable to disease (O'Brien et al. 1985). Careful attention is paid in determining breeding pairs in order to increase the genetic diversity of the species. Subpopulations of cheetah have been reintroduced to several areas with variable success (Skinner and Chimimba 2005). As aforementioned, their large range requirements make it difficult to introduce cheetah in sufficient numbers without exceeding the carrying capacity of an area (Lindsey 2011). Managers must also be concerned about the presence of adequate prey species at reintroduction sites (Hayward et al. 2006). According to research in South Africa, 20 subpopulations of 10 cheetah or 10 subpopulations of 15 cheetah are required to maintain genetic diversity such that the species can overcome stochastic events and predation (Lindsey 2011).

**Manage other stressors** – Less than 50% of the total cheetah population are in protected areas; this makes the threat from farmers and ranchers more significant (Durant 2008). There is an inflated perception of the cheetah as a predator of livestock (Durant 2008; Skinner and Chimimba 2005). Due to their large, overlapping ranges landowners often overestimate the number of cheetah in the area (Marker et al. 2008). In addition, cheetah differ from other large carnivores in that they hunt during the day and more frequently (Meyers 1975). Developing techniques to resolve conflicts between cheetah and people is a conservation priority.

## COMMON ELAND *Tragelaphus oryx* (Pallas)


Photo by: Hans Hillewaert via Wikimedia Commons

The common eland is the largest African antelope; both males and females have spiral horns (Skinner and Chimimba 2005). Eland range across sub-Saharan Africa and have a total estimated population of 136,000 (IUCN 2008c). This is a dramatic decline since the 1970s and much of the eland's native range has been lost to human population expansion; nevertheless, the IUCN lists the common eland as a species of "Least Concern" (IUCN 2008c). Today half of all common eland occur in protected areas, where some populations are increasing while others are on the decline (IUCN 2008c). In the southern tip of Africa most populations are reintroduced, while those populations to the north are mostly native (Pappas 2002). Approximately 30% of the common eland population is on private land, where they tend to be increasing (IUCN 2008c). Eland are highly valued as a trophy animal and have even been domesticated in several areas (IUCN 2008c). The common eland is a source of leather and rich milk, which it can produce in abundance (Pappas 2002). In one day an eland can produce up to 15 pounds of milk which can be preserved longer than that from domestic cattle (Pappas 2002).

### ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

**Range requirements** – Common eland are not territorial but do need large areas to feed because of their size; thus, they maintain a high inter-individual distance (Skinner and Chimimba 2005; Pappas 2002). However, larger groups can form during the wet season when more food is available (Pappas 2002). Eland herds of 10 to 50 have been seen in the highveld and as many as 300 in the lowveld (La Grange 2006). Large ranges are also necessary to accommodate the movement of common eland based on seasonal food availability (IUCN 2008c).

**Disease** – The common eland is prone to a variety of disease, including: foot-and-mouth, tuberculosis and roundworms (Bothma et al. 2002). However, the eland is resistant to trypanosomiasis, also known as sleeping sickness (Pappas 2002).

**Thermoregulation** – In order to conserve energy and water, common eland allow their body temperature to rise significantly throughout the day (Taylor 1970). However, there are physiological limits to this strategy (e.g., selective brain cooling does not occur) which require eland to avoid exposure to heat when possible (Skinner and Chimimba 2005). Eland do not orient their bodies based on the angle of the sun like other animals, but they do actively seek shade on hot days (Skinner and Chimimba 2005; Pappas 2002). Eland will feed in the early morning and after sunset to avoid the heat of the day (Pappas 2002; Bothma et al. 2002).

### ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

**Water independent** – Common eland can survive without frequent access to water because they can obtain enough moisture from their food (IUCN 2008c). Therefore, they can move greater distances between water sources (Skinner and Chimimba 2005). Eland actually prefer arid areas, but do not inhabit areas with less than 200 mm/year rainfall (La Grange 2006; Bothma et al. 2002). Several seasons of drought will reduce population of common eland (Pappas 2002).

**Dispersal** – Common eland are primarily browsers and move seasonally based on the availability of food and water (IUCN 2008c; Pappas 2002). Eland will move up and down mountains and seek burned areas with sprouting grass (Skinner and Chimimba 2005). Despite being the slowest of the African antelopes, the common eland can trot for a considerable distance (Skinner and Chimimba 2005; La Grange 2006). Eland are known to be exceptional jumpers and can easily jump two meters high from a standing position (La Grange 2006; Skinner and Chimimba 2005). Even if they cannot leap over a fence, eland are so heavy that they can break through it (Pappas 2002).

**Wide distribution** – The IUCN (2008c) classes the common eland as one of the most adaptable ruminants because they can inhabit a wide range of habitats. This flexibility is due to both their water-independence and use of a variety of food resources (Skinner and Chimimba 2005). Elands inhabit subdesert, acacia savanna, miombo woodland and alpine moorlands up to 4,900 meters in elevation (IUCN 2008c). They will use open plains but avoid thick forests (Pappas 2002).

**Varied diet** – In order to survive without surface water, eland must have access to succulent forage (Skinner and Chimimba 2005). That said, they will eat whatever is available during each season—grass in summer and browse in winter (Skinner and Chimimba 2005; Pappas 2002). The flowering plants that eland prefer are high in protein (Pappas 2002). Research shows that common eland select from available food based on the fiber content, which is related to the leaf to stem ratio (Owen-Smith 2002).

**Population size and trends** – Common eland are a valuable commercial species and as such their numbers are increasing on private farms and conservancies (Skinner and Chimimba 2005; IUCN 2008c). This will help to counterbalance decreases in the overall population due to habitat lost to human settlement (IUCN 2008c). Any developments that impinge upon their food supply can affect the population densities and mortality rates of common eland (Pappas 2002). Natural population increases will range from 11 to 38% (the mean is 20%) depending on rainfall, veld condition and predation (Bothma et al. 2002). Typically, eland breed in spring and early summer and calve in October (Bothma et al. 2002; La Grange 2006). However, different levels in nutrition can result in variations in peak breeding season between populations in different areas (Skinner and Chimimba 2005).

### POTENTIAL EXPOSURE

Common eland range throughout sub-Saharan Africa. Models predict an annual mean increase in precipitation in eastern Africa, where temperatures will increase by 1.8 to 4.3°C (IPCC 2007). In contrast, the eland that range across southern Africa will face extremely hotter and drier conditions; the IPCC (2007) predicts annual change in precipitation of -12% to +6% (IPCC 2007). The decrease in precipitation will be as much as -43% to +3% during the dry months; the frequency of extreme dry seasons will increase from 20 to 23% (IPCC 2007). Average annual temperatures in southern Africa will increase by 1.9 to 4.8°C (IPCC 2007).

### ADAPTATION STRATEGIES

**Reintroduction** – The common eland has been reintroduced widely throughout its historic range (Skinner and Chimimba 2005; IUCN 2008c).

**Captive breeding** – Due in part to poor mothering, calf survival in captivity is low (Pappas 2002). Despite their commercial value, eland are not as easy to ranch as cattle (Bothma et al. 2002). In captivity common eland need a great quantity of expensive food to supplement their diet (Pappas 2002).

**Managing Other Stressors** – The same qualities that make eland attractive to ranchers make them a target of poachers. Eland have thick hides and tender meat which are prized by poachers (Shurter 2012). Some recent research shows that environmental pollution in South Africa had an endocrine-disrupting effect on male eland (Bornman et al. 2010).

## **GEMSBOK** *Oryx gazelle* (Linnaeus)

The gemsbok is a large antelope native to Botswana, Namibia, South Africa and Zimbabwe (IUCN 2008b). Although the gemsbok is a species of "Least Concern," the related, but genetically distinct, species *O. beisa* found in northeast Africa is "Near Threatened" (IUCN 2008b; Osmers et al. 2011). Gemsbok occur in arid savannahs and bushland (Bothma et al. 2002). Today an estimated 373,000 gemsbok range widely across southern Africa; however, this is an extensive decrease in its previous numbers and distribution (East 1999; IUCN 2008b). In the last 10 to 20 years, reintroductions of gemsbok to private land and protected areas have helped the population stabilize and increase (IUCN 2008b). The long, slender horns of the gemsbok make it a valuable trophy animal and its quality meat makes it a desirable ranching animal (Bothma et al. 2002). The economic importance of gemsbok is reflected in the fact that 45% of its population occurs on private land (IUCN 2008b).

Photo by: Hans Hillewaert
via Wikimedia Commons

### ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

**Disease** – Although translocation and ranching will help increase the population, this can expose gemsbok to disease and keep them from thriving (Meltzer 1993). Introduced gemsbok can fall victim to disease, paralysis and death caused by tick infestations (Fourie and Vrahimis 1989; Bothma et al. 2002).

### ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

**Water independent** – Gemsbok need 2.5 to 4 liters of water a day, but can meet this need even in the absence of surface water (Skinner and Chimimba 2005). They dig for water-storing roots, tsama melons, bulbs and tubers (IUCN 2008b). Gemsbok often graze at night to take advantage of dew on the grass (Bothma et al. 2002). In addition, gemsbok have several adaptations to help conserve water. Their digestive tract is structured to promote intensive reabsorption of water and they change their breathing to reduce evaporation from their respiratory tract (Skinner and Chimimba 2005). Heat stress and dehydration do not affect the food intake of gemsbok (Maloiy et al. 2008). If necessary, gemsbok can tolerate brackish water to supplement their moisture (Skinner and Chimimba 2005; Bothma et al. 2002).

**Thermoregulation** – Gemsbok can tolerate desert heat while conserving moisture. Like some other large antelope, a gemsbok's body heat rises along with the ambient temperature to avoid sweating (Taylor 1970). This excess heat is dissipated hours later during the cool night (Skinner and Chimimba 2005). Gemsbok have a rete, a network of blood vessels at the base of the skull, that may help cool their brains even when their body heat is elevated (Skinner and Chimimba 2005; Maloney 2002).

**Small range requirements** – Gemsbok do not migrate and can survive within a small area of arid savanna (IUCN 2008b). The average range for a gemsbok is about 21 square km (Bothma et al. 2002). Although males are territorial, they are tolerant of others which allows for overlapping territories and greater population density (Skinner and Chimimba 2005). When food is abundant, gemsbok form herds of up to 300, but when food is in short supply these large herds break up (Skinner and Chimimba 2005).

**Varied diet** – Gemsbok are mostly grazers, but they browse for other food during the dry season when grass is sparse (IUCN 2008b). They can feed on diverse plant communities in a variety of arid habitats such as savannas, dunes and sandy soils (Skinner and Chimimba 2005).

**Reproduction** – Gemsbok do not have a specific breeding season, but rainfall does affect calving patterns (Skinner and Chimimba 2005). Calving peaks from August to September and is closer to August when the food supply is optimal (Bothma et al. 2002).

## POTENTIAL EXPOSURE

According to climate change models, gemsbok in southern Africa will face even hotter and drier conditions. The IPCC predicts that annual precipitation will change -12% to 6+% (IPCC 2007). The decrease in precipitation will be as much as -43% to +3% during the dry months; the frequency of extreme dry seasons will increase from 20 to 23% (IPCC 2007). Average annual temperatures in southern Africa will increase by 1.9 to 4.8°C (IPCC 2007).

## ADAPTATION STRATEGIES

**Ranching and Reintroduction** – The economic value of gemsbok for trophy hunting and ranching helps ensure the safety, and increase, of the population (IUCN 2008b). Gemsbok have been successfully reintroduced to private and protected land in areas of their former range (Skinner and Chimimba 2005).

**Managing Other Stressors** – The same high-quality meat that makes gemsbok a desirable ranching species also makes it a target for illegal bushmeat hunting (East 1999).

Photo by: Bries via Wikimedia Commons

## **GIRAFFE** *Giraffa camelopardalis* (Linnaeus)

Giraffes, the tallest living land mammals, are iconic to the African landscape. Several subspecies of giraffe have been described (Fennessy and Brown 2010). These subspecies are characterized by variations in coloration patterns usually distinct to particular geographic locations (Skinner and Chimimba 2005). Giraffe are widespread and thus listed as a species of "Least Concern" by IUCN; however, it is noted that the total population of 100,000 seems to be decreasing which may warrant a change this listing once more census data is available (Fennessy and Brown 2010). Southern populations are increasing whereas northern populations have decreased as a result of habitat degradation and poaching (Fennessy and Brown 2010). In the past, giraffe were distributed throughout Africa, but now populations are patchy and discontinuous (Skinner and Chimimba 2005). Giraffe habitat can range from scrub to woodland; however, they do not inhabit forests or open plains (Skinner and Chimimba 2005).

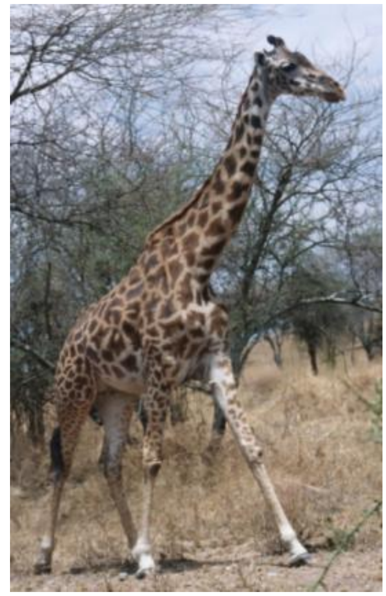
Photo by: Martha Surridge

### ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

**Dispersal** – Giraffes cannot cross rivers (MacClintock 1973) and that may put a limit on their ability to disperse naturally in response to climate changes. In captivity, water is an effective barrier to contain giraffe (Skinner and Chimimba 2005). Also giraffe can fall victim to low-strung telephone and power lines (MacClintock 1973).

**Disease** – Giraffe are less affected by rinderpest than other ruminants (MacClintock 1973); nevertheless, rinderpest has been cited as a contributing factor to local loss of giraffe (Skinner and Chimimba 2005). They are also susceptible to outbreaks of anthrax, bacterial disease and epidemics of gastroenteritis (MacClintock 1973).

### ELEMENT OF RESILIENCY TO CLIMATE CHANGE

**Water independence** – Unlike most ungulate species, giraffe do not seem very sensitive to a lack of rainfall during the dry season (Hulme et al. 2001). Because they are browsers, giraffe are considered a water-independent species (Du Toit 2002a). This means that although they may drink frequently when water is available, they can survive on the moisture from their forage (Skinner and Chimimba 2005). Depending on the temperature, giraffes consume 8 to 38 liters of water. When water is limited, they can last 3 to 8 days without drinking if green foliage is available (MacClintock 1973; Owen-Smith 1988). Giraffe have no set drinking time but, particularly in the dry season, they tend to visit waterholes during the day to avoid lions (Owen-Smith 1988; Du Toit 2002a). The sheer height of giraffe allows them to browse where other herbivores cannot, but that is not the species' only competitive advantage. Because they are less dependent on water, giraffes can search for food farther away from rivers than other browsing species. This is also fortunate because during the dry season lions concentrate their hunting efforts near water holes (MacClintock 1973).

**Thermoregulation** – When the day is hottest, giraffe may rest or seek shade, but unlike many other ungulates, giraffe do not need to seek shade to cool themselves during hot weather (MacClintock 1973). Instead they may continue to feed throughout the heat of midday (Owen-Smith 1988). Giraffe have several characteristics to help reduce their body heat. They are physiologically incapable of panting; instead giraffe rely on evaporation of the nasal mucosa to cool blood before it goes to the brain (Skinner and Chimimba 2005). They also have sweat glands to dissipate body heat (Skinner and Chimimba 2005). Due to a special network of arteries at the base of the skull, known as a rete, giraffe tolerate high body temperatures while running. In addition, the rete may contribute to the giraffe's tolerance of hot weather and limited water (MacClintock 1973).

**Varied diet** – People predominantly associate giraffes with *Acacia* trees. Giraffe are selective browsers and *Acacia* provide the bulk of their diet (Fennessy and Brown 2010); however, they also browse on a variety of other species. Protein-rich leaves and shoots, fruit and flowers are preferred but their diet varies depending on what is seasonally available (Skinner and Chimimba 2005). During the dry season, giraffe increasingly rely on evergreen and semi-evergreen species (Owen-Smith 1988). They devote more of their time to searching for browse, instead of resting and ruminating. If their food supply is very limited, giraffes will even consume bark (MacClintock 1973).

**Dispersal** – Giraffe can jump fences 1.4 meters high (Bothma et al. 2002). Thus, the expansion of ranches may have less impact on giraffe compared to wildebeest and some other ungulates. Giraffe do not compete with grazing cattle (Spinage 1968) and they have successfully been reintroduced to protected areas and private farmland (Skinner and Chimimba 2005).

**Reproductive Biology** – There is no set breeding season for giraffes; instead, they can breed throughout the year unlike most ungulates (MacClintock 1973). Peak conception is during the wet season, which coincides with optimal nutrition for females in oestrus. Over 50% of giraffe give birth at the onset of the dry season. Female giraffe reach sexual maturity after 4 years and their calving interval ranges from 1.5 to 2 years (Owen-Smith 1988).

**Broad historical distribution** – Giraffe range throughout sub-Saharan Africa wherever trees occur. However, the expansion of human populations, particularly in western Africa, has reduced their range (Fennessy and Brown 2010).

### POTENTIAL EXPOSURE

The broad distribution of giraffe across sub-Saharan Africa means that the species will be exposed to various manifestations of climate change. Models predict a significant decrease in the winter (dry season) precipitation for southern Africa; whereas, there will be an annual mean increase in eastern Africa (IPCC 2007). Temperatures will increase by 1.9 to 4.8°C in the south and 1.8 to 4.3°C in the east (IPCC 2007). There are two subpopulations of giraffe in western Africa (Skinner and Chimimba 2005) where the projected temperature increase is 1.8 to 4.7°C (IPCC 2007). The frequency of extremely wet seasons will increase by 22% in western Africa (IPCC 2007).

### ADAPTION STRATEGIES

**Translocation** – Relocation can compensate for any barriers to giraffes dispersing naturally. Throughout southern Africa giraffe have been successfully reintroduced to historical portions of their range (Fennessy and Brown 2010). Several methods have been developed to capture and transport one or more giraffe in the wild (La Grange 2006).

**Supplemental water** – Giraffes have learned to drink from cattle troughs (MacClintock 1973). This indicates that, although it is not strictly necessary, giraffes could make use of supplemental water.

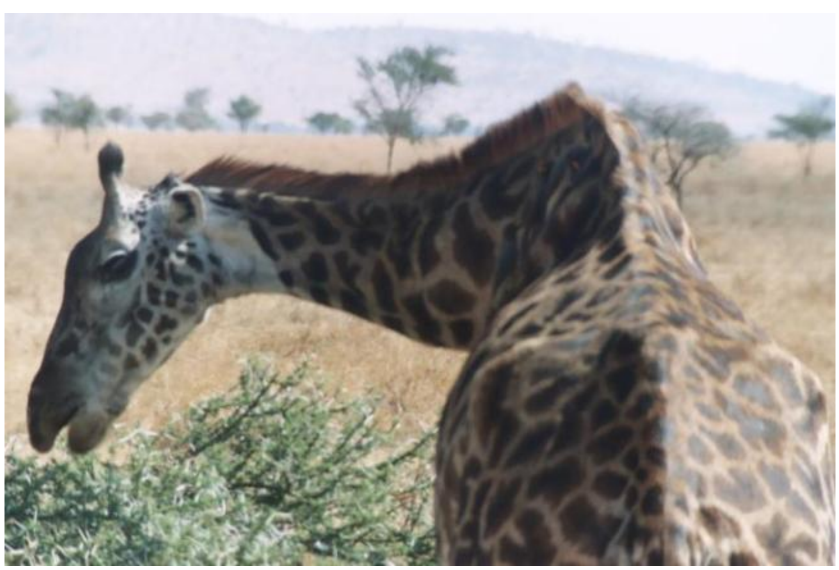

Photo by: Martha Surridge

## **Greater Kudu** *Tragelaphus strepsiceros* (Pallas)

The greater kudu is a large antelope recognizable by large ears and twisting horns on the males. The IUCN lists greater kudu as a species of "Least Concern" because it has a large and generally stable population (IUCN 2008d). It is estimated that the total population is 482,000 and the largest subpopulations are on private farmland in Namibia and South Africa (IUCN 2008d). The largest protected population of 3,300 is in Kruger National Park in South Africa (Skinner and Chimimba 2005). The northern populations are smaller and less stable than those in the south (IUCN 2008d).

Photo by: Jonathan Mawdsley

The greater kudu is very valuable for trophy hunting and as game meat. In South Africa, greater kudu is the second most used species for game meat (Hoffman and Laubscher 2009). It is more productive than any domesticated animal in terms of high quality meat (Bothma and du Toit 2002). Despite the demand for hunting trophies and cultivation of their native habitat, the overall numbers of the greater kudus should remain satisfactory (Nersting and Arctander 2001). In fact, the success of the safari and game meat industries will be integral to its persistence on private land (IUCN 2008d).

### ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

**Sensitivity to severe drought** – Although greater kudu can subsist on browse and no water, there is a limit to this resilience. When vegetation is very dry, greater kudu will become water-dependent (IUCN 2008d).

**Resource availability** – The population density of greater kudu depends on resource availability, which is dictated by rainfall (Owen-Smith 1990). In one example, a 30% increase in rainfall resulted in a higher density of kudu (Owen-Smith 2011). Greater kudu are adapted to browse on a variety of vegetation, but the reduced nutrition of browse during a drought increases the amount needed (Owen-Smith 2002; Dorgeloh 2001). Males in poor condition at the end of the rutting season may not be able to endure the dry season (Skinner and Chimimba 2005).

**Predation** – Greater kudu are at high risk for predation, particularly from lions (Pays 2012). Therefore, the kudu greatly increase their vigilance near lions (Periquet 2010). The dry season is especially dangerous for greater kudu. In Kruger National Park, 40% of lion kills were during the three months of the dry season (Owen-Smith 2002). The predation in Kruger drags the annual population growth rate from 20% down to 14.8% (Bothma and du Toit 2002). If they are being targeted by hunters, instead of lions, greater kudu will do more of their drinking under the cover of darkness (Crosmary 2011).

**Disease** – Greater kudu are exceptionally susceptible to anthrax and tuberculosis, which spreads quickly throughout a herd (Du Toit et al. 2002).

### ELEMENTS OF RESILIENCE TO CLIMATE CHANGE

**Water independent** – Greater kudu will drink 7 to 9 liters of water when it is hot; however, they are not dependent on surface water (Du Toit et al. 2002). When there is a normal amount of annual rainfall, greater kudu can subsist on the moisture from their food (Skinner and Chimimba 2005). Nevertheless, greater kudu are mostly found in woodlands along watercourses (Skinner and Chimimba 2005).

**Habitat flexibility** – The greater kudu continues to survive in broad range of habitats including scrub land and abandoned fields (IUCN 2008d). Unlike most large animals, kudu can thrive even when close to human settlements provided there is enough cover (IUCN 2008d).

**Heat tolerance** – Extreme temperatures only affect the foraging habits of greater kudu about one day in seven (Owen-Smith 1997). In this case extreme temperature is defined as above 36°C in the wet season and 30°C in the dry season (Owen-Smith 2002). At the other extreme, the excessive cold in late winter and early spring can kill kudu (Bothma and du Toit 2002).

**Diet** – Greater kudu are browsers that eat a wider variety of species than any other bovids in its southern range (Skinner and Chimimba 2005). In particular, they will expand their diet when food becomes less abundant in the dry season (Owen-Smith 1997, 2002).

**Reproductive Biology** – Greater kudu mate from April to June, gestate for 270 days and calve from January to February (Skinner and Chimimba 2005). On average the annual growth rate for greater kudu is 20%; however, this falls to 13% during drought and increases to 28% under better conditions (Bothma and du Toit 2002).

### Potential Exposure

The broad distribution of greater kudu across sub-Saharan Africa means that the species will be exposed to various manifestations of climate change. Models predict a significant decrease in the winter (dry season) precipitation for southern Africa; whereas, there will be an annual mean increase in eastern Africa (IPCC 2007). Temperatures will increase by 1.9 to 4.8°C in the south and 1.8 to 4.3°C in the east (IPCC 2007).

### Adaptation Strategies

**Game management** – The continued economic importance of the greater kudu is its best defense. At present, overhunting and habitat loss in the north is counterbalanced by management of the species in other areas (IUCN 2008d).

Photo by: Jonathan Mawdsley

## **Hippopotamus** *Hippopotamus amphibius* (Linnaeus)

Photo by: Martha Surridge

The hippopotamus is one of the most familiar and widespread African mammals, occurring in rivers, streams, lakes and estuaries throughout sub-Saharan Africa. As noted by Eltringham (1993) and Skinner and Chimimba (2005), there has been considerable contraction of the species' range in historic times, including the complete loss of populations near the Cape of Good Hope and in the lower Nile valley. Declines continue at the present time; the IUCN (Lewison and Oliver 2008) estimated a 7 to 20% loss in total population size between 1996 and 2006. The causes of the declines are generally acknowledged to be human exploitation of the species and habitat loss (Lewison and Oliver 2008). Because these threats are ongoing and not expected to be reduced in the future, the species is currently considered "Vulnerable" by the IUCN (Lewison and Oliver 2008). Local increases have been reported in Kenya (Kanga et al. 2011), suggesting that the species may be able to recover its former abundance if threats are reduced. Three to five subspecies have been recognized by various authors (reviewed by Skinner and Chimimba 2005) although these putative taxa cannot be distinguished in the wild (Eltringham 1993). Okello et al. (2005) reviewed the status of several of these taxa using mitochondrial DNA variation.

### ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

**Water** – Hippopotamuses spend over 12 hours per day in water (Noirard et al. 2008) and are critically dependent on the presence of freshwater pools, ponds and rivers which contain water deep enough to submerge their entire bodies (Skinner and Chimimba 2005). During the dry season, hippos will utilize a wide range of permanent water bodies, including anthropogenic ponds, dams and weirs (Skinner and Chimimba 2005). Drought conditions which reduce the available aquatic habitat for hippopotamuses could potentially lead to adverse effects on the species, including population declines, increased crowding and disease, and more intraspecific violence due to increased contact between animals.

**Food** – Hippopotamuses are selective grazers, feeding on certain preferred grass species in riverine and riparian areas (Skinner and Chimimba 2005). In areas with a year-round water supply, food availability is the major regulator of hippo populations (Harrison et al. 2008). Preferred grass species reported in the literature include *Panicum maximum*, *Urochloa mosambicensis*, *Cynodon dactylon*, *Hemarthria altissima*, *Echinochloa pyramidalis* and *Ischaemum fasciculatum* (Scotcher 1978; Skinner and Chimimba 2005). Individual populations may have their own dietary preferences based on local availability and abundance of preferred grass species (Skinner and Chimimba 2005). Changes in vegetation species composition which occur as a result of climate change could significantly alter the availability of forage for hippopotamuses. Hippos are also well-known raiders of human agricultural crops; therefore, changes in the availability of preferred grass species could lead to increased attempts by hippos to utilize human crops as food.

**Population Decline** – As noted above, the area occupied by this species has declined during historic times, culminating in a recent population decline of 7 to 20% range-wide (Lewison and Oliver 2008). Numerous localized extirpations have resulted in a highly fragmented distribution, with many small, isolated populations across sub-Saharan Africa (Skinner and Chimimba 2005). Reductions in population size and geographic range may limit the ability of hippopotamus populations to respond to climate change. Population decreases may result in the loss 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 hippopotamuses to shift geographically in response to changing climatic conditions.

### ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

**Broad Distribution** – Despite the historic and recent declines in hippo populations, the species remains widespread over much of sub-Saharan Africa (Eltringham 1993; Skinner and Chimimba 2005; Lewison and Oliver 2008). Across this range, individual populations have been exposed to considerable variation in temperature and precipitation regimes (Skinner and Chimimba 2005), suggesting that the species may be fairly tolerant of climatic fluctuations, so long as its basic water requirements are met.

### POTENTIAL EXPOSURE

The broad distribution of the hippopotamus across sub-Saharan Africa means that the species will 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** – Both historic and recent declines in hippopotamus populations are clearly being driven by a combination of human exploitation and habitat loss (Lewison and Oliver 2008). Both their meat and ivory tusks make hippos attractive targets for poachers. To date, climate change has not been implicated in hippo declines, although the close association of the species with deep water suggests that it is potentially vulnerable to climate change. Changes in precipitation regimes, hydrological flow regimes and groundwater levels all have the potential to create or eliminate hippopotamus habitat. Drought conditions which reduce the available habitat for hippopotamuses could lead to adverse effects such as population declines, increased crowding and disease, and increased intraspecific violence due to increased contact between animals. Reducing the effects of anthropogenic stressors on hippopotamus populations should help provide the species with greater flexibility to adapt to changing climatic conditions.

Photo by: Martha Surridge

## **OKAPI** *Okapia johnstoni* (Sclater)

Photo by: Charles Miller via the Wikimedia Commons

The okapi is best known as the only close relative of giraffe. Okapis live solitary lives and have strong hearing enabling them to be very elusive; a fact which prevented western scientists from discovering them until the 20th century (MacClintock 1973). Endemic to the forests of the Congo, the okapi ranges on both sides of the river at elevations between 500 to 1,500 meters (IUCN 2008a). The estimated population is 10,000 to 35,000 and is considered stable; however, the IUCN (2008a) lists the okapi as "Near Threatened." The range of the okapi is limited to gallery forests and it will not persist in open or disturbed habitats (IUCN 2008a). Potential economic expansion into protected areas in the Democratic Republic of Congo would imperil the species' core habitat (IUCN 2008a).

### ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

**Restricted Range** – Okapi live only in the Congolese rainforest and not in any of the surrounding habitats. The range of okapi is limited by ecological and physiographical conditions preventing dispersal, not by specific species of plants (Bodmer and Rabb 1992). Their range is bounded by high montane forests to the east, swamp forest to the west, the Sahel/Soudan savanna to the north, and open woodland to the south (Bodmer and Rabb 1992). Like giraffe, the structure of okapi hooves prevents them from crossing rivers or occupying marshy areas (MacClintock 1973). Thus, okapi cannot migrate up into high montane forests (Lindsey 1999).

**Browse requirements** – The okapi diet comes mostly from 30 species, but they browse from over 200 species (Lindsey 1999). Although this variety might imply a flexible diet, okapi must have access to succulent forage. In captivity okapi do not drink frequently and it is likely that in the wild they rely on vegetation for their moisture. When given dry hay, they can develop mouth abscesses and require drinking water (Lindsey 1999). Okapi browse selectively on secondary growth in forest openings caused by fallen trees (Lindsey 1999). Only 5% of the forest includes areas of tree fall, but these areas provide large share of the okapi's food (Bodmer and Rabb 1992).

**Thermoregulation** – The okapi is diurnal but avoids the heat of the day. Because of its dark skin, the okapi seeks shade from bright sunlight to reduce heat absorption (Lindsey et al. 1999). The skull does have air sinuses but they do not extend to the back of the head like in the giraffe (Spinage 1968). Calves do not thermoregulate for their first two months until the intense nesting phase is over (Lindsey 1999).

### ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

**Reproductive biology** – Instead of a seasonal breeding cycle, female okapi are in oestrus every two weeks (Lindsey 1999). Although okapi may calve at anytime, they usually do so during the two wet seasons (December to February and June to August) after a 14-month gestation period (MacClintock 1973; Lindsey 1999). The calves remain hidden in the undergrowth rather than following their mothers during the day (MacClintock 1973).

### POTENTIAL EXPOSURE

The IPCC (2007) predicts that the temperature in western Africa will increase 1.8 to 4.7°C. Models suggest a change in precipitation anywhere from -9% to +13% (IPCC 2007). As a result of climate change, Thuiller (2006) predicts high species loss in central Africa, mostly in the Congo Basin. The already-limited range of the okapi will become even more constricted. Unlike other species, okapi cannot easily shift to cooler areas. The frequency of extremely wet seasons will increase by 22% in western Africa (IPCC).

## ADAPTATION STRATEGIES

**Captive Breeding** – Most of our knowledge of okapis is based on scientific studies of captive animals (Lindsey 1999). There is a Species Survival Plan to manage over 80 okapi in 22 AZA-accredited zoos (AZA 2012b). Keeping okapis in zoos protects against total extinction but they do require an injection of new genetic material (Lindsey 1999). Most species in captivity are descendents of the Epulu population in the Ituri Forest (Bodmer and Rabb 1992). Okapi are difficult to keep in captivity; because they are susceptible to over 30 species of worms and there is a poor survival rate for calves in their first year (Lindsay 1999). Unless their enclosures are cleaned regularly and thoroughly, okapi can develop a variety of parasitic and bacterial infections (Gijzen 1959).

**Managing Other Stressors** – The incursion of active settlements and bushmeat hunting are major threats to okapi (IUCN 2008a). The loss of its already-limited habitat is a more immediate problem than any climate-induced changes.

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# **Black Wildebeest** *Connochaetes gnou* (Zimmermann)

Black wildebeest, also known as white-tailed gnu, are considerably smaller than blue wildebeest (Skinner and Chimimba 2005; La Grange 2006). The IUCN lists black wildebeest as a species of "Least Concern" because there are no major threats to the estimated population of 18,000 (IUCN 2008f). The vast majority (80%) of black wildebeest are on private farms and conservancies (IUCN 2008f). They are native to South Africa, Swaziland and Lesotho and have also been introduced to Namibia (IUCN 2008f). The black wildebeest has similar habitat requirements to that of the blue wildebeest (Richter 2006). They graze on short grasses and occasionally forbs (Bothma et al. 2002). Black wildebeest can be found on open plain grasslands, especially those in the highveld at over 1,300 meters above sea level (Skinner and Chimimba 2005; Bothma et al. 2002; IUCN 2008f).

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## ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

**Dispersal** – Unlike blue wildebeest, black wildebeest do not make long migrations but they do move at a local scale to follow the rains (Skinner and Chimimba 2005; Richter 2006). Eighty percent of black wildebeest are on private land and thus cannot migrate at all (IUCN 2008f; Richter 2006). In addition to fencing, the encroachment of human settlements into their historic range restricts the movement of black wildebeest (Skinner and Chimimba 2005). Overgrazing becomes a problem when wildebeest are constrained to a single area (Bothma et al. 2002).

**Water requirements** – Black wildebeest are water dependent and require 7 liters per day (Du Toit 2002a). They will drink in the early morning and late afternoon; their intake increases during the summer (Richter 2006). Black wildebeest graze on short grass and will not move more than 500 meters away from water or shade (Bothma et al. 2002).

**Sensitivity to temperature** – Black wildebeest are burdened by intense radiant heat during the summer (Skinner and Chimimba 2005). To avoid the midday heat, black wildebeest become almost totally inactive between 10am and 4pm (Richter 2006). Black wildebeest spend nearly half the day lying down; this reduces the reflection heat radiation from the ground (Skinner and Chimimba 2005). When it is cooler, black wildebeest will alter their position to get the most sun possible (Skinner and Chimimba 2005).

**Disease** – Black wildebeest have fallen victim to sporadic outbreaks of anthrax (Richter 2006). They are a carrier of malignant catterhal fever which can be passed to nearby cattle herds. In the past, this was a reason to restrict the movement of the wildebeest (Skinner and Chimimba 2005).

## ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

**Current distribution** – Black wildebeest habitat is at a higher elevation than that of blue wildebeest. This should provide a buffer to temperature increases in the short term. However, if the temperature increases even more, then black wildebeest will have limited ability to move to higher elevations for refuge. Today there are few large predators in the range of black wildebeest which will improve their survival rate (Skinner and Chimimba 2005).

**Reproductive biology** – Black wildebeest breed seasonally within 2 to 3 weeks after the first rain (Richter 2006). Peak mating occurs in mid-March and mid-April and calving in November through January (Richter 2006; Bothma et al. 2002). Black wildebeest are one of the most productive herbivores in South Africa; the annual population growth rate is between 20 to 33% per year (Bothma et al. 2002).

## POTENTIAL EXPOSURE

In future, black wildebeest must cope with hotter and much drier conditions. Black wildebeest live in southern Africa, where the IPCC (2007) predicts annual change in precipitation of -12% to +6%. The decrease in precipitation will be as much as -43% to +3% during the dry months; the frequency of extreme dry seasons will increase from 20 to 23% (IPCC 2007). Average annual temperatures in southern Africa will increase by 1.9 to 4.8°C (IPCC 2007).

## ADAPTATION STRATEGIES

**Provide water and shade** – Given the inability of black wildebeest to range far from available water and shade, supplements could be provided to help wildebeest adapt to climate change.

**Reintroduction** – Reintroduction from private farms to reserves has helped the black wildebeest population recover from past exploitation (Skinner and Chimimba 2005). They have been reintroduced to western Swaziland and western Lesotho. In addition 7,000 black wildebeest have been introduced to private farmland in Namibia, which is beyond its historic range (IUCN 2008f). Wildebeest have been bred in captivity by zoos around the world (Richter 2006). The main caveat to ranching black wildebeest is to prevent any interbreeding with blue wildebeest (Bothma and et al. 2002).

Photo by: Martha Surridge

## **BLUE WILDEBEEST** *Connochaetes taurinus* (Burchell)

Blue wildebeest, also known as common wildebeest or brindled gnu, are listed as a species of "Least Concern" because they are numerous and widespread across sub-Saharan Africa (IUCN 2008e). Wildebeest range across Angola, Botswana, Kenya, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe (IUCN 2008e). They live in savannahs with nearby shrubs and trees and eat short grasses (Bothma et al. 2002). There are five regional subspecies of blue wildebeest; all but the Eastern White-bearded subpopulation are stable or increasing. The Serengeti-Mara region is home to 70% of the total estimated population of 1,550,000 (IUCN 2008e).

Photo by: Martha Surridge

### ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

**Dispersal** – For many, the spectacle of wildebeest charging across rivers during the "Great Migration" is symbolic of the wilds of Africa (Spinage 1962). Unfortunately, barriers to this movement are a major threat to blue wildebeest. Blue wildebeest do not jump over fences (Bothma et al. 2002); thus, fences blocking migration routes have caused mass die-offs in the past (IUCN 2008e; Skinner and Chimimba 2005). The portion of the Serengeti-Mara population in Kenya has declined to 25% of its size at the end of the 1970s (Serneels and Lambin 2001). In addition to long migrations, blue wildebeest move in the direction of localized rainstorms in pursuit of fresh grass (Skinner and Chimimba 2005). In the past, large herds of blue wildebeest in southern Africa migrated northeast after a season of 25 to 50% less than average rainfall (Skinner and Chimimba 2005). Now some blue wildebeest populations are becoming constrained to protected areas and do not have the option to disperse (IUCN 2008e). Competition with livestock and loss of surface water are also threats. Climate change will affect rainfall patterns across Africa and wildebeest may not be able to migrate in search of better conditions.

**Water and shade requirements** – Blue wildebeest frequent savannah woodland habitats because nearby shade and water are essential to their survival (Skinner and Chimimba 2005). As grazers blue wildebeest are water-dependent; they require nine liters of water a day (Du Toit 2002a). During the dry season, they need to drink at least every two days (IUCN 2008e) and will not stray far from permanent water (Bothma et al. 2002). Field observations show that blue wildebeest will restrict their activity to within 10 km of fresh water (Skinner and Chimimba 2005). Wildebeest seek shade during the heat of midday; this refuge is so important that wildebeest rarely go more than 100 meters from shade (Bothma et al. 2002). When shade is not available, blue wildebeest will alter the angle of their body position relative to the sun to avoid as much direct sunlight as possible (Skinner and Chimimba 2005).

**Sensitivity to drought** – Large migrations are spurred by the need for water and may not occur during seasons with heavy rain (Skinner and Chimimba 2005). The increased frequency of drought due to climate change will increase the need for blue wildebeest to make long migrations. This in turn can raise the odds of a herd encountering a fence or other obstacle, which can mean death.

**Diet** – Blue wildebeest are highly selective grazers that prefer short grass. They are usually found grazing alongside zebra, which first eat the tall grass (Bothma et al. 2002). Fires can also create areas of new grass growth (Skinner and Chimimba 2005). The amount of rainfall has an effect on the nutritional quality of forage. Greener grass has a greater nutritional content (Owen-Smith 2002; Ben-Shahar and Coe 1992) and blue wildebeest will make short migrations in response to local rainfall changes (Bothma et al. 2002). Historically, the mass migrations of blue wildebeest have been in sync with the peaks of quality forage and favorable environmental conditions in an area (Bothma et al. 2002). Climate change has already made the wet season drier and dry season wetter; therefore, blue wildebeest are arriving two months earlier for the wet season and move south when land there is still barren. This can result in lower quality forage when females are lactating (Chidumayo et al. 2011). Above average precipitation can also have a negative impact on forage quality because heavy rainfall can promote higher fiber content in the grass which reduces the nutrient value (Owen-Smith 2002).

**Predation** – There are some conflicting possibilities of the effect of drought on predation of blue wildebeest; however, it seems that blue wildebeest fare better than many other herbivore species. Lions will switch their prey based on environmental conditions and relative prey abundance (Skinner and Chimimba 2005). A study in Kruger National Park in South Africa found that although blue wildebeest and zebra are the preferred prey of lion, the two species are less susceptible to being killed under conditions of low rainfall (Owen-Smith and Mills 2008). Drought can weaken animals, but blue wildebeest on the Serengeti can migrate to other habitats to reduce the risk of predation. This ability has been a crucial factor in maintaining the abundance of the blue wildebeest species (Owen-Smith 2008). The negative impact of above average rainfall on the grass preferred by blue wildebeest can lead to greater predation by lions (Skinner and Chimimba 2005). Male blue wildebeest, which normally stay in the same area year-round, may abandon their territories once they have been weakened by drought (Skinner and Chimimba 2005). This may make female herds more vulnerable to predation.

**Disease** – Blue wildebeest can be seriously affected by rinderpest and foot-and-mouth disease (Richter 2006). Proximity to livestock can increase the odds of disease transmission.

### ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

**Broad historical and current distribution** – Blue wildebeest were widely distributed across sub-Saharan Africa. This exposed the historic population to a wide range of temperature and precipitation regimes and vegetation communities. Although they have been restricted to smaller subpopulations, they are still considered numerous and widespread (IUCN 2008e). In addition, blue wildebeest have been introduced to areas outside of the past range and re-introduced to other areas (IUCN 2008e).

**Reproductive biology** – The mating season of blue wildebeest is linked to lunar cycles with rut from March to May and birth November to December (Chidumayo et al. 2011; Bothma et al. 2002). Blue wildebeest in the KwaZulu-Natal region have a second breeding season in August (Skinner and Chimimba 2005). The annual population growth rate ranges from 28 to 38%; however, the large abundance of predators in Kruger National Park reduces that average to 17.4% (Bothma et al. 2002). It is possible that the general breeding pattern for blue wildebeest may be influenced by climate conditions (Skinner and Chimimba 2005).

**Translocation methods developed** – Wildlife biologists have developed methods for capturing and relocating large blue wildebeest herds (La Grange 2006). The species has been reintroduced to reserves throughout southern Africa (Skinner and Chimimba 2005). It is vital that blue wildebeest on ranges are not given an opportunity to interbreed with black wildebeest (Bothma et al 2002).

### POTENTIAL EXPOSURE

The vast majority of blue wildebeest are in eastern Africa (IUCN 2008e), where models predict an annual mean increase in precipitation (IPCC 2007). Temperatures will increase by 1.8 to 4.3°C in the east (IPCC 2007). In contrast, the blue wildebeest that range across southern Africa will face extremely drier conditions (IPCC 2007).

### ADAPTATION STRATEGIES

**Provide water and shade** – Given the inability of blue wildebeest to range far from available water and shade, supplements can be provided to help wildebeest to adapt to climate change.

**Improve habitat connectivity** – Blue wildebeest will naturally migrate to areas with better water and forage. Increased temperatures and drought due to climate changes will necessitate such dispersal. Barriers created by veterinary fences must be removed to allow for short- and long-range migrations.

**Managing Other Stressors** – Competition with livestock has caused population declines of blue wildebeest in the Kalahari (Skinner and Chimimba 2005). This threat can be mitigated by repairing the damage to grasslands caused by livestock grazing (Hogan et al. 2006). When wildebeest must migrate away from protected reserves, they will be vulnerable to illegal hunting and habitat loss to human settlements (IUCN 2008e).

## ZEBRA

There are three species of zebra: Grevy's (*E. grevyi*), mountain (*E. zebra*) and plains (*E. burchelli*). These species have different numbers of chromosomes (Grevy's 46, plains 44, mountain 32) and do not interbreed (MacClintock 1976). The Grevy's is the most distantly related of the zebra species (Groves 1974). The IUCN lists plains zebra as a species of "Least Concern," but mountain zebra are considered "Vulnerable," and Grevy's are "Endangered." Plains zebra appear in mixed herds with Grevy's in Kenya and with mountain zebra in Namibia and Angola (Bauer et al. 1994; Bothma et al. 2002; Grubb 1981). The location, ecology and behavior of the three species vary such that they have some different vulnerabilities to climate change.

## GREVY'S ZEBRA *Equus grevyi* (Oustalet)

The Grevy's is an "Endangered" species of zebra that has experienced a great reduction in population and range (IUCN 2011b). They are distinguishable by their narrow, closely set stripes (Groves 1974). According to the IUCN (2011b), Grevy's have suffered a greater range reduction than any other African mammal. The species now exists in a few small subpopulations in Kenya and Ethiopia. The total population of Grevy's is estimated at 1,966 to 2,447 (IUCN 2011b).

Photo by: Martha Surridge

### ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

**Genetic bottleneck** – The population trend for Grevy's zebra is now considered stable; however, the population fell a drastic 55% between 1988 and 2007 (IUCN 2011b). Prior to that, the population declined 65% from 1971 to 1978 (Churcher 1993). By 2008 the total population was only 755 (IUCN 2011b). Although the total population of Grevy's zebra has rebounded, it is still relatively small.

**Water requirements** – Grevy's zebra are less dependent on water than plains zebra or cattle (MacClintock 1976; Churcher 1993). Nevertheless, during the dry season they must have access to a permanent water source (IUCN 2011b). Grevy's zebra drink daily in the morning and afternoon. They can go three days without water if necessary and can even dig up to 60 cm deep to find water (Churcher 1993). However, lactating females must drink every 1 to 2 days (IUCN 2011b).

**Intraspecific interactions** – Unlike the other zebra species, Grevy's do not maintain cohesive herds. Instead, the males defend permanent territories (Groves 1974). The quality of the territory, which may be 2 to 12 square km, is determined by the presence of water and food (IUCN 2011b). Confrontation with other males brings the risk of injury, but males will defend their territories against other males only if a female in oestrous is present (Churcher 1993). These males are often located in dry, rocky areas within their territory (MacClintock 1976) and may only travel to drink water every 2 to 3 days (Churcher 1993). Grazing groups frequent flatter scrub terrain and occupy a 3 to 10 square km territory (MacClintock 1976).

**Predation** – Zebra are the second most common prey of lions and are also hunted by hyena and wild dogs (MacClintock 1976). Territorial males are at greater risk of predation (Churcher 1993).

**Disease** – Zebra may contract anthrax, tetanus and rinderpest (Churcher 1993). Fifty-three Grevy's zebra and 26 plains zebra fell victim to an anthrax outbreak in the Wamba area of southern Samburu, Kenya (Muoria et al. 2007). An analysis of gastro-intestinal parasites shows that Grevy's zebra carry several parasites which are also seen in other wild animals, people and livestock (Muoria 2005). Zebra that survive rinderpest become immune to the disease (Churcher 1993).

## ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

**Dispersal** – Grevy's zebra are mobile and will migrate 80+ km to find grass and water (MacClintock 1976; IUCN 2011b). Zebra graze on long grass and move on to other areas to allow the grass to regrow (Owen-Smith 2002). The density of Grevy's zebra groups will depend on the availability of resources (IUCN 2011b). When it is very dry, Grevy's zebra will coalesce into large herds within a day's reach of water (Churcher 1993).

**Adapted to arid conditions** – Grevy's zebra inhabit arid and semi-arid grass and shrub lands that have a permanent source of water (IUCN 2011b). Several authors have noted that Grevy's zebra are well adapted to arid regions (Churcher 1993). Grevy's zebra are nearly two-times larger than plains zebra (400 kg versus 220 kg) and large body size is better suited to hot conditions (Churcher 1993). Black and white stripes both absorb and reflect heat; the comparatively narrow stripes of the Grevy's zebra may provide extra protection (MacClintock 1976). In addition, their shiny hide reflects more than half of the heat from solar radiation (MacClintock 1976).

**Diet** – Zebra graze on tall grass; wildebeest usually consume the short grass that remains (Bothma et al. 2002). Because they have grinding teeth and hindgut fermentation, zebra can eat coarse grass of low nutritional value that other species cannot digest well (Churcher 1993). During a drought, zebra can get up to 30% of their diet from browse (IUCN 2011b). Their fibrous dung shows that zebra conserve water better than cattle do (Bothma et al. 2002). Lactating females and bachelors eat green, short grass more frequently than others (Sundaresan at al. 2008).

**Reproductive biology** – Grevy's zebra have the longest gestation period (390 days) of any equid. Including gestation and nursing, it takes 665 days to produce one offspring (Churcher 1993). Sexual activity peaks in August to September resulting in births between August and September after the rains of the following year (Churcher 1993). Territorial males do not move during the dry season and cannot mate once females move away to find food and water (MacClintock 1976). Nevertheless, actual breeding success may be independent of rainfall (Churcher 1993).

## POTENTIAL EXPOSURE

In the future, Grevy's zebra will encounter a hotter climate with some more rainfall. Models predict an annual mean increase in precipitation in eastern Africa, where temperatures will increase by 1.8 to 4.3°C (IPCC 2007).

## ADAPTATION STRATEGIES

**Translocation and captive breeding** – Grevy's zebra have been successfully reintroduced to areas in their historic range (Churcher 1993). Zoos have been breeding and managing Grevy's zebra in accordance with a Species Survival Plan since 1987 (AZA 2012c).

**Managing Other Stressors** – Grevy's zebra are sometimes poached for their meat and decorative hides (Churcher 1993). Some of the major threats to Grevy's zebra are competition for food and water with pastoral people and domestic livestock (IUCN 2011b). Habitat loss and overgrazing are also serious problems (IUCN 2011b).

## **MOUNTAIN ZEBRA** *Equus zebra* (Linnaeus)

There are two subspecies of mountain zebra: Cape mountain zebra (*E. z. zebra*) in the Cape Province of South Africa and Hartmann's mountain zebra (*E. z. harmannae*) in Namibia (Novellie 2008; Groves 1974; Penzhorn 1998). The behavior and appearance of these subspecies are alike (Bothma et al. 2002). The IUCN (2011c) lists mountain zebra as "Vulnerable" and estimates the total population at 9,000.

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### **ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE**

**Restricted range** – Mountain zebra live in rugged mountainous terrain up to 2,000 meters (IUCN 2011c; Skinner and Chimimba 2005). A large heart is one indication that Mountain zebra are adapted to living at high altitudes (MacClintock 1976). They require diverse grass species and perennial water sources (IUCN 2011c). Cape mountain zebra prefer the foothills of mountains but Hartmann's zebra prefer higher mountain slopes (Bothma et al. 2002). Both subspecies use ravines to take shelter from harsh weather (Bothma et al. 2002). Cape mountain zebra are now restricted to only a few isolated areas in the Cape Province of South Africa (Groves 1974). In fact, nearly all of the Cape mountain zebra are animals that were relocated from the Mountain Zebra National Park (IUCN 2011c). This means that the subpopulations will become genetically isolated which makes the species more vulnerable to climate change.

**Water requirements** – Mountain zebra are water-dependent and drink daily (Du Toit 2002a; Skinner and Chimimba 2005). Hartmann's zebra actively seek shade in midday to reduce the loss of water to evaporation; however, Cape zebra do not (Penzhorn 1998). The Hartmann's subspecies is able to drink only every third day which makes it less water-dependent than plains zebra (Groves 1974; MacClintock 1976). Mountain zebra can also dig for water if necessary (MacClintock 1976). Both subspecies live in arid mountain habitat with only 150 to 450 mm annual rainfall; thus, they need to have a sufficient source of surface water (Bothma et al. 2002).

**Population size and growth rate** – The IUCN (2011c) estimates that there are currently 9,000 mature mountain zebra. The Cape mountain zebra is much rarer than Hartmann's (Groves 1974). With the help of reintroduction the Cape mountain zebra population has rebounded from less than 100 in the 1950s to an estimated 1,500, of which 500 are mature (IUCN 2011c). However, the Hartmann's zebra has been declining due to harvesting for their skins (IUCN 2011c). There is not enough data to discern the overall trend of the mountain zebra population. The natural population growth for mountain zebra is 20% (Bothma et al. 2002). Mountain zebra gestate for 365 days; although births may occur year-round, there is a peak in summer. When it is dry in the spring, conception occurs later in the season (Penzhorn 1998).

### **ELEMENTS OF RESILIENCY TO CLIMATE CHANGE**

**Diet** – Mountain zebra feed on short, coarse grasses which predominate in arid conditions (Bothma et al. 2002; Penzhorn 1998). They can also browse if environmental conditions make forage scarce (IUCN 2011c).

**Social Structure** – Mountain zebra congregate in small harems, which include 3 to 5 mares and their foals, lead by a single stallion (IUCN 2011c; Groves 1974). Non-breeding zebra form bachelor herds (IUCN 2011c). Plains zebra have the same social structure (Groves 1974). Mountain zebra are not territorial and group ranges may overlap as much as 90% (Penzhorn 1998; Bothma et al. 2002; Skinner and Chimimba 2005). Male Grevy's zebra require larger areas to maintain individual territories, whereas mountain and plains zebra may tolerate a larger population density. Unlike plains zebra, the mountain zebra do not tend to associate with wildebeest (Groves 1974).

## POTENTIAL EXPOSURE

Mountain zebra live in the coastal mountains of southern Africa, where they will be confronted with significantly drier conditions. The IPCC predicts an annual change in precipitation of -12% to +6% (IPCC 2007). The decrease in precipitation will be as much as

-43% to +3% during the dry months; the frequency of extreme dry seasons will increase from 20 to 23% (IPCC 2007). Average annual temperatures in southern Africa will increase by 1.9 to 4.8°C (IPCC 2007).

## ADAPTATION STRATEGIES

**Provide water** – Mountain zebra are water-dependent; thus, ensuring the continued presence of surface water is an important climate adaptation strategy for this species. Artificial water sources can even enable mountain zebra to expand into previously unsuitable areas. For example, this tactic helped Hartmann's mountain zebra to occupy habitat beyond the historic range (IUCN 2011c).

**Reintroduction and Translocation** – Cape mountain zebra only occur in a few populations, but they have been successfully reintroduced to their historical range (IUCN 2011c). Altering the fire regime in preferred zebra habitat can open some areas for mountain zebra (Chadwick and Watson 2007). Translocation will help improve the genetic diversity of the Cape mountain zebra metapopulation (IUCN 2011c). However, in doing so, care must be taken to prevent any crossing with Hartmann's mountain zebra (IUCN 2011c; La Grange 2006). There is also the risk of disease transmission during translocation. In 1987, zebra translocated from Namibia to Spain spread African horse sickness (Meltzer 1993). Zoos have been managing Hartmann's zebra in accordance with a Species Survival Plan since 1990 (AZA 2012a).

**Managing Other Stressors** – In Namibia, Hartmann's mountain zebra are threatened by livestock and farming activities that create barriers to their water sources (IUCN 2011c). The skins of Hartmann's mountain zebra skins are being traded commercially at a rate potentially higher than their rate of population growth (IUCN 2011c). It is important to monitor Hartmann's mountain zebra to ascertain population trends.

Photo by: Martha Surridge

## PLAINS (BURCHELL'S) ZEBRA *Equus Quagga* (Boddaert)

The plains zebra is also known as the Burchell's or common zebra. This is the only one of the three zebra species that is not under threat; thus, the IUCN lists the plains zebra as a species of "Least Concern." Plains zebra are widespread and common across much of sub-Saharan Africa (IUCN 2011a). The approximately 660,000 strong population ranges both in and outside of protected areas (IUCN 2011a).

Photo by: Martha Surridge

### ELEMENTS OF VULNERABILITY TO CLIMATE CHANGE

**Water dependent** – Plains zebra are water-dependent and require 12 liters of water per day (Du Toit 2002a). They move in response to the availability of water (Bothma et al. 2002; Skinner and Chimimba 2005). Plains zebra can travel to grazing areas during the wet season, but in the dry season they must congregate near permanent rivers or pools (IUCN 2011a). Dry conditions reduce the probability of conception (Grubb 1981).

### ELEMENTS OF RESILIENCY TO CLIMATE CHANGE

**Broad distribution** – Plains zebra are widespread across Africa, including: Botswana, Congo, Ethiopia, Kenya, Malawi, Mozambique, Namibia, Rwanda, Somalia, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe (IUCN 2011a). This is a resilient species that can easily recover from population declines, assuming they have suitable habitat (IUCN 2011a). Plains zebra naturally migrate across open savannahs and grasslands based on the availability of food, water or newly burned areas (Bothma et al. 2002).

**Diet** – Plains zebra are not very selective and will graze on short or tall grass (Bothma et al. 2002; Skinner and Chimimba 2005). They eat whatever grass is most abundant and accessible even if it is tough and has little protein (Grubb 1981). On average, a plains zebra eats 7.8 kg of dry matter each day, which is double the forage intake of a blue wildebeest (Bothma et al. 2002). Their low digestive efficiency is offset by increased consumption (Bothma et al. 2002). Plains zebra are the first to return to burned areas to eat the freshly growing grass (MacClintock 1976).

**Reproductive biology** – Although plains zebra mate seasonally, the timing of births is not as restricted as it is for other ungulates on the plain (Grubb 1981). That said, most conceptions and births occur during the wet season, after a 360 to 375 day gestation period (Grubb 1981).

### POTENTIAL EXPOSURE

Most plains zebra are in eastern Africa, where models predict an annual mean increase in precipitation (IPCC 2007). Temperatures will increase by 1.8 to 4.3°C in the east (IPCC 2007). Some plains zebra live in the northernmost parts of Namibia, Botswana and South Africa (Skinner and Chimimba 2005). According to the IPCC (2007), there will be a decrease in precipitation in southern Africa including more frequent extremes in the dry season.

### ADAPTATION STRATEGIES

**Monitor and Provide Water** – There are no immediate conservation actions required for plains zebra; however, it is important to monitor the population to determine if threats emerge (IUCN 2011a). If necessary, provision of water would be a useful strategy to help plains zebra adapt to climate change.

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