Chapter 1

Impacts of Climate Change and Climate Variability on Wildlife Resources in Southern Africa: Experience from Selected Protected Areas in Zimbabwe

Olga L. Kupika, Edson Gandiwa, Shakkie Kativu and
Godwell Nhamo

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.70470

Abstract

Climate change and variability pose a threat to wildlife resources in semi-arid savannahs. With examples from selected protected areas in Southern Africa, this chapter highlights studies on detected climate changes particularly rainfall and temperature, outlines the predicted and observed impacts of climate change and variability on wildlife resources in savannah ecosystems and highlights the adaptation and mitigation strategies and implications for conservation. Literature indicates that Southern Africa is characterised by highly variable, erratic and unpredictable rainfall and increasing temperature coupled with an increasing trend in climate-related extreme events such as frequent droughts, cyclones and heat waves. Drought, in particular, has led to death in several wildlife species. This has implications on long-term survival of the species. Changes in rainfall and temperature patterns influence habitat quality and consequently abundance of distribution of wildlife species. Large herbivores such as elephants and hippopotamus in particular are vulnerable to climate change due to their ecology, whereas other species are less vulnerable. Climate-related extreme events, coupled with other anthropogenic stressors, interact to influence changes in abundance and distribution of wildlife resources. Understanding the influence of these climatic factors on wildlife resources is vital for adaptive management and protection of biodiversity.

Keywords: adaptation, biodiversity, climate, management, mitigation, resilience

1. Introduction

Climate change poses major risks to global biodiversity in the twenty-first century [1] as it affects ecosystems processes, flora and fauna abundances and distribution [2]. Climate change refers to any change in the state of climate that is reflected in shifts in mean climatic variables over extended periods, typically decades or longer [3]. Climate change may result from natural internal processes within the climate system [4] or variations in natural or persistent anthropogenic external variability [5]. Climate results from fluctuations in the mean state or other climate statistics on temporal scales beyond those of individual weather events [6]. Climate change impacts, such as increased water shortages due to persistent droughts, present a threat to wildlife resources and consequently wildlife-dependent livelihoods in Africa. Thus, managing wildlife resources populations requires an understanding of the nature, magnitude and distribution of current and future climate impacts [7].

The term wildlife collectively refers to all forms of undomesticated flora and fauna found in terrestrial or aquatic environments [8]. In the present study, wildlife resources refer to faunal or floral species with potential benefit to human kind. Climate change has greater impacts on livelihoods of people in developing countries due to their low adaptive capacity [9]. However, this chapter focuses on terrestrial and semi-aquatic vertebrates, specifically mammals and their habitats. In Southern Africa, wildlife species promote the lives and livelihoods of local communities, particularly those living adjacent to protected areas [10]. Such communities generate revenue from activities such as eco-tourism, safari and consumptive hunting and bush meat trading. Therefore, there are huge economic losses associated with floods, droughts and wildfire. Against this backdrop, different mechanisms have been put in place to encourage climate change adaptation and mitigation in the biodiversity sector at global, regional and national levels [11].

The Intergovernmental Panel on Climate Change [12] projects a rise in surface temperature over the twenty-first century under all assessed emission scenarios. Global averaged temperatures are projected to increase by between 0.15 and 0.3°C per decade [13]. The frequency and intensity of heat waves are also likely to be more frequent and prolonged [14]. Many regions are likely to experience more frequent and extreme precipitation events. According to the Intergovernmental Panel on Climate Change (IPCC) [15], there is high likelihood that climate-related extremes, such as heat waves, droughts, floods, cyclones and wildfires, will expose some ecosystems, rendering them vulnerable to climate variability. Climate models project increased aridity and persistent droughts in the twenty-first century for most of Africa, Southern Europe, Middle East, Southeast Asia and Australia [16].

According to the Intergovernmental Panel on Climate Change [17], climatic changes are occurring at a faster rate than expected, particularly in Southern Africa. The IPCC predicts a 10 to 24% in mammalian species in sub-Saharan Africa national parks [13]. Climate change due to natural variability is therefore affecting terrestrial biological systems. Diffenbaugh and Field noted that there has been significant rise in temperatures of terrestrial ecosystems due to global warming [18]. Climate change directly affects ecosystems through seasonal changes in rainfall and temperature and indirectly through other disturbances such as fire and drought [11]. The IPCC [12] also notes that generally there is high confidence that several terrestrial, freshwater and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances and species interactions in response to climate change. Based on available scientific literature, the IPCC Fourth Assessment Report (AR4) also reports that there is medium confidence that terrestrial ecosystems could have faced some impacts in Africa in recent decades due to climate change [12]. Additional threats from extensive land use and degradation, changes in frequency and severity of extreme events and interactions with other stresses [18] further threaten the resilience of terrestrial ecosystems. However, the

IPCC AR4 acknowledges that there is gap in knowledge on the climate change impacts across many regions.

Common effects of climate change on species and ecosystems include (1) changes in life-history events or phenology, (2) effects on demographic rates, such as survival and fecundity, (3) reductions in population size and (4) shifts in species distributions. Climate change poses direct and indirect effects on herbivore species [19] through changes in the fitness, survival and reproductive success [20]. In semiarid ecosystems, climatic changes in frequency and severity of droughts are likely to exacerbate the effects of drought on forage availability, which can feed back to regulate reproduction and offspring recruitment among ungulates [21]. Forrest et al. [22] highlighted that climate change is likely to affect the persistence of large, space-requiring species through habitat shifts, loss and fragmentation.

Understanding the effects of climate change and variability on wildlife species is vital in conservation biology and wildlife management [21], especially proactive management and formulation of conservation status decisions [23]. Large mammalian herbivores are key drivers of rangeland dynamics [24] hence assessing the effects of climate change and variability on these populations is essential for the stewardship of ecosystems and biodiversity [25]. The World Wide Foundation [26] noted that the impacts of climate change on global biodiversity and how biological species may (or may not) adapt are yet to be quantified. To date, few studies have assessed the impacts of climate change and variability on resources that support wildlife in Southern Africa [27].

Using case study examples, this chapter reviews the potential impacts of climate change and variability on wildlife resources in some protected areas in Southern Africa. The objectives of this chapter are to: (1) highlight studies on detected climate changes particularly rainfall and temperature, (2) outline the predicted and observed impacts of climate change and variability on wildlife resources in Southern Africa and (3) highlight climate change adaptation and mitigation strategies and implications for conservation.

2. Materials and methods

This study adopted both quantitative and qualitative methods to obtain data on the effects of climate change and variability on mammalian species on selected national parks in Zimbabwe. We conducted a review existing literature (1980–2015) from peer-reviewed journal articles, books, edited book chapters, electronic academic theses, technical reports from Google Scholar, Scopus and Web of Science covering issues on climate change, climate variability and wildlife resources in Southern Africa. Data were also obtained from unpublished internal scientific reports and management plans from the Zimbabwe Parks and Wildlife Management Authority (ZPWMA) and other and external reports from policy documents related to biodiversity and climate change in Southern Africa. Technical reports and public publications from key stakeholders, such as the International Union for Conservation of Nature (IUCN), World Wide Fund for Nature (WWF) and African Wildlife Foundation (AWF), were also reviewed. The following keywords or phrases were used: “climate change,” “climate variability,” “impacts/effects,” “wildlife,” “mammals,” “biodiversity,” “ecosystems,” “drought,” “rainfall,” “temperature,” “herbivores,” “global environmental change,” “plants,” “flora” and “fauna” with a combination of “AND” between the keywords to retrieve the relevant literature.

Secondary data on rainfall, temperature and large mammal surveys for the period 1960–2015 were also collected from published and unpublished reports from the Zimbabwe Parks and Wildlife Management Authority. Secondary data were either adopted or used to plot graphs showing large mammal trends in relation to rainfall and temperature. Data were collected between August 2016 and February 2017. Literature obtained from all the documents was categorised under the following themes: (1) historical trends in selected mammals in relation to climate variables (1980–2015), (2) predicted and observed impacts of climate change and variability on wildlife resources in selected protected areas in Southern Africa and (3) implications for conservation. For further analysis, case studies from Zimbabwe (**Figure 1**) were used to highlight impacts of climate change on wildlife resources.

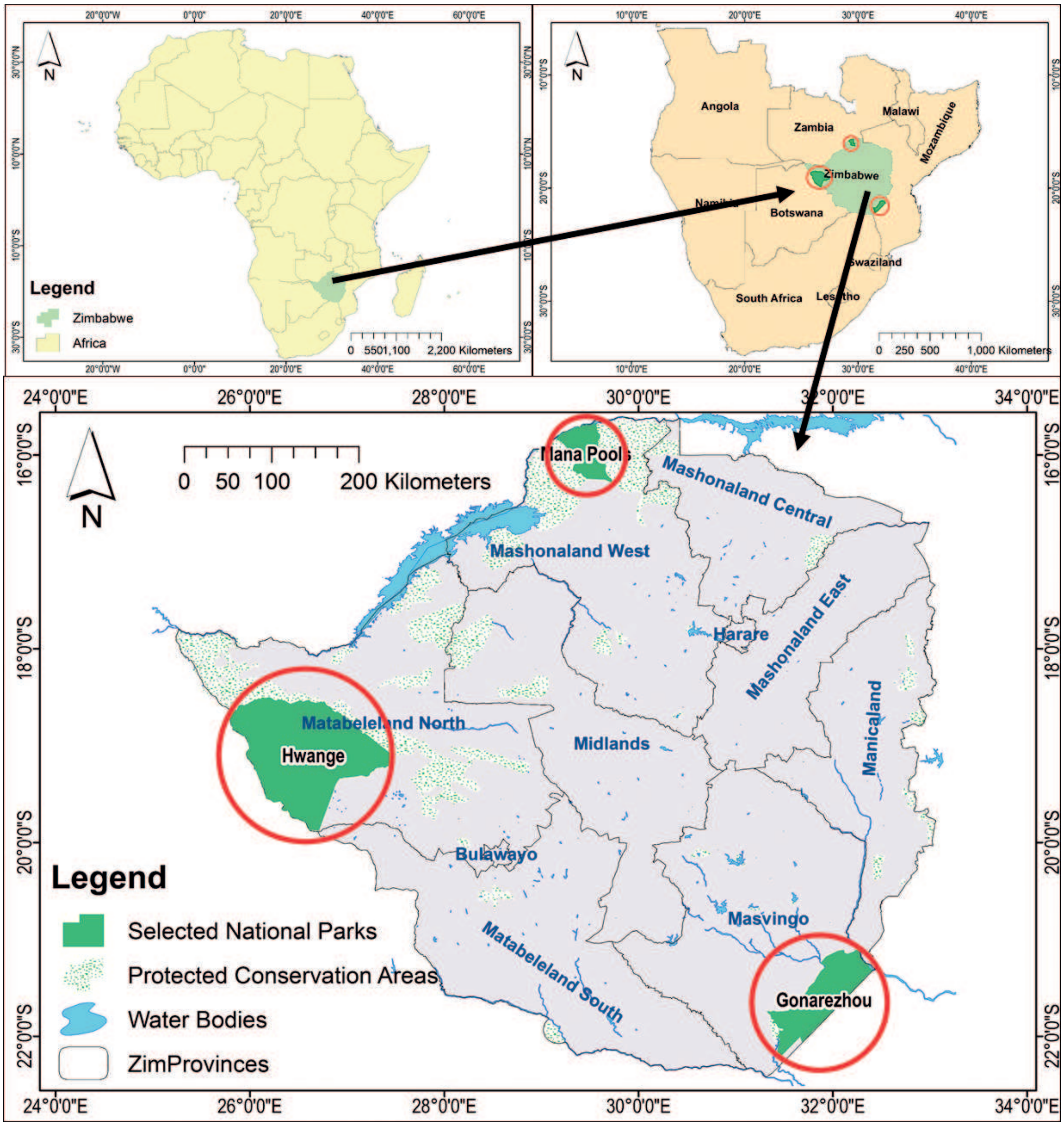

Figure 1. Location of the largest protected areas (used as case studies) in Zimbabwe.

3. Results and discussion

This section highlights predicted and observed trends in rainfall and temperatures across Southern Africa and their implications on wildlife resources. Impacts of climate change on selected wildlife species and some of the predicted and observed impacts of climate change and variability are subsequently highlighted for selected protected areas. Implications in terms of adaptation and mitigation for conservation are also discussed.

3.1. Rainfall and temperature trends: implications for wildlife resources

Global warming has caused a gradual reduction in annual rainfall across Africa over the past 50 years [24]. Projections of precipitation and runoff in Africa suggest a decrease of up to 10% in precipitation in most of Southern Africa (including Zimbabwe) by 2050 [28]. This reduction could reduce the distribution and availability of both food and surface water for animal species [24]. Rainfall is the main climatic factor governing herbivore population dynamics across Africa [29, 30]. African wildlife resources are therefore likely to be subjected to climate warming due to rising temperatures and extreme events, such as droughts and floods [27]. Thus, climate-induced extreme events threaten some of the large protected areas that have been designated to conserve much of Africa's magnificent biodiversity [31].

The IPCC [3] predicts that Africa is projected to have 'above-average' climate change in the twenty-first century. Thus, global warming will have the greatest effects on biodiversity in the continent [32]. Chamaille-Jammes et al. [33] noted that climate change is predicted to affect both the mean annual rainfall and its seasonal distribution over the African continent. Thus, climate warming has a potential to directly affect wildlife resources through shifts in onset and duration of rainy seasons and drought on wildlife species, reduction in species distribution ranges, alteration in abundance and diversity of mammals, changes in calving and population growth rates, changes in juvenile survival of most ungulates and changes in species richness of birds and mammals [27]. Consequently, these changes in wildlife species abundance and distribution will have direct serious negative impacts on ecotourism and game hunting activities.

Southern Africa is characterised by highly variable climatic conditions associated with fluctuating temperature and rainfall. The region is prone to frequent and intense El Nino-Southern Oscillation (ENSO) events, leading to widespread drought in some areas and widespread flooding in others [34]. According to the IPCC [12], mean seasonal temperatures are predicted to increase, and El Nino-Southern Oscillation effects, fires and severe weather anomalies are more likely to be more common in Southern Africa. Projections of precipitation and runoff in Africa suggest a decrease of up to 10% in precipitation in most of Southern Africa by 2050 [28]. Most of Southern Africa is prone to extreme events such as droughts and floods [35] and climate warming, which are the major climate change factors that are likely to affect wildlife resources in Southern Africa [27]. Climate can affect mammalian populations indirectly by excessive temperatures or rainfall, through bottom-up effects on food plant productivity or top-down effects on predator efficiency [36]. Bottom-up control mechanisms are based on the view that herbivore populations are limited by forage quality and quantity [37].

Climate variables, particularly rainfall and temperature, generally influence habitat quantity and quality within savannah ecosystems thereby affecting the structure, composition and dynamics of wildlife species. Temperature and rainfall display complex temporal variation changing from place to place across the earth. These key climatic factors determine plant productivity and hence animal food availability [38]. For instance, several studies have also reported on the influence of rainfall, especially during the dry season, on the availability of forage of adequate quality and large herbivore population performance [29, 30, 39–41]. Rainfall controls primary production [33] and ungulate grazer populations across the African savannah [42–45]. Strong relationships between abundance and rainfall suggest that rainfall underpins the dynamics of African savannah ungulates and that changes in rainfall due to global warming may markedly alter the abundance and diversity of these mammals [41].

Generally in African savannah, wildlife populations grow in wet season and decline in dry season such that there tends to be fluctuations from year to year depending on seasonal conditions. Variability in rainfall influences animal populations in the savannahs [46]. For instance, a study carried out in Kruger National Park sought to establish the extent to which the population composition of the common impala (*Aepyceros melampus* (Lichtenstein, 1812), Burchell's zebra (*Equus burchelli*), blue wildebeest (*Connochaetes taurinus*), greater kudu (*Tragelaphus strepsiceros)*, giraffe (*Giraffa camelopardalis*), common waterbuck (*Kobus ellipsiprymnus)*, warthog (*Phacochoerus aethiopicus*), sable antelope (*Hippotragus niger*), tsessebe (*Damaliscus lunatus)* and roan antelope (*Hippotragus equinus)* were associated with changes in rainfall and prey availability [30]. Multiple regression models fitted to survival estimates indicated that juvenile survival was sensitive to annual variability in rainfall for most of these species, especially in the dry season [30]. Rainfall components affected adult survival in several of the declining species, while negative density dependence in adult survival was evident for three of the four species that maintained high abundance [30]. Dixon et al. [47] also estimated that approximately 66% on nyala and zebra in Kruger National Park, South Africa are likely to be lost as a result of climate change.

Ungulates respond to rainfall fluctuations through movements, survival [46] and reproductive phenology [36]. Rainfall influences the composition of the herbaceous layer and its quality; forage vegetation growth and food production during the wet season and retention of green foliage during the dry season [30]. Ogutu et al. [48] investigated the influence of rainfall and temperature fluctuations on the dynamics and abundance of an insularised and compressed impala population. The study observed that whilst births negatively correlated with rainfall, high rainfall depressed reproductive success in impalas [43].

Episodic and local droughts help limit elephant (*Loxodonta Africana*) population numbers [24]. Shrader et al. [24] revealed that annual variations in rainfall and the confounding effects of water provision and fences influence elephant survival rates across different sites in Africa. In Southern Africa, wildlife resources also depend on water resources, which are derived from major basins such as Limpopo and Zambezi. For instance, the Zambezi basin contains a number of important national parks in Southern Africa that are likely to be negatively impacted by such climate-induced changes in the hydrological cycle. Analysis of the Zambezi system in Southern Africa has revealed that the basin has low runoff efficiency and a high dryness index, which indicates its high sensitivity to climate change. Climate warming is predicted to result in runoff decreases even when precipitation increases due to the large hydrological role played by evaporation, especially from wetlands. Thus, increased runoff from loss of forest cover will only worsen water losses from wetland areas due to evaporation that is predicted under a warmer climate.

3.2. Projected impacts of climate change on wildlife resources

General circulation models (GCMs) are numerical models that simulate the physical processes of climate [7]. The GCMs have been used in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC AR4) as a basis for forecasting (**Table 1**) future climate as a primary determinant of species distributions and ecosystem processes impacts [7].

Global models predict that climate in Southern Africa is warming at a faster rate than has been predicted although no clear trend in rainfall patterns has been observed. Southern Africa is characterised by extremely variable rainfall patterns coupled with drought episodes. On the other hand, extreme events, such as droughts and floods, appear to have increased in frequency in the recent past. The IPCC [12] predicts that specific areas likely to be affected by climate change in Africa include African Rift Mountains, the Zambian and Angolan Highlands and the Cape Province of South Africa. Under the high-end A2 scenario, 12–39% and 10–48% of the Earth's terrestrial surface may respectively experience novel and disappearing climates by 2100 AD [6]. Corresponding projections for the low-end B1 scenario are 4–20% and 4–20%. Terrestrial fauna biodiversity in Africa is concentrated in the moist forests, woodlands and savannahs. Loss or alterations of terrestrial habitats by climate change will likely impact these species as they struggle to adapt to changing conditions [6]. The following section outlines observed impacts of climate change on selected species in selected protected areas in Southern Africa.

Projected impacts	Model	Source
About 50,000 African plant species impacted: substantial reductions in areas of suitable climate for 81–97% of the 5,197 African plants examined, 25–42% lose all area by 2085	Africa Hadley Centre Third Generation Coupled GCM (HadCM3) for years 2025, 2055, 2085, plus other models—shifts in climate suitability examined	[50]
Future distribution in 2050 of 975 endemic plant species in Southern Africa distributed among seven life forms endemic flora of Southern Africa (Namibia and South Africa) on average decreases with 41% in species richness among habitats and with 39% on species distribution range for the most optimistic scenario	SDMs were fitted to climatic data using the BIOMOD package in SPLUS	[51]
Fynbos and succulent Karoo biomes: losses of between 51 and 61%	Africa for years 2025, 2055, 2085, plus other models—shifts in climate suitability examined	[52]
Projected losses by 2050, critically endangered taxa (e.g. Proteaceae) in South Africa: losses increase, and up to 2% of the 227 taxa become extinct increase, and up to 2% of the 227 taxa become extinct	(HadCM2 IS92aGGa)	[49]

Source: Adopted from IPCC [50].

Table 1. Projected impacts of climate change on wildlife resources in Africa.

3.2.1. Case study 1: Gonarezhou National Park, South Eastern Lowveld, Zimbabwe

Gonarezhou National Park (GNP), the second largest national park in Zimbabwe, is located in southeastern Lowveld between latitudes 21° 00′–22° 15′ S and longitudes 30°15′–32°30′ E [37]. The park was established in 1975 [50]. The park covers total area of approximately 5053 km^2 and has a mean altitude of 400 m above sea level [50]. GNP is part of the Great Limpopo Transfrontier Conservation Area (GLTFCA), Southern Africa [50]. The park has a hot and semi-arid climate, which is characterised by highly seasonal and unreliable rainfall quantity and duration [51]. The park receives an average annual precipitation of approximately 466 mm with high inter-annual variability [52]. GNP has three distinct climatic seasons namely hot and wet (November–April), cool and dry (May–August) and hot and dry (September–October). Average monthly maximum temperatures are 25.9°C in July and 36°C in January, whereas average monthly minimum temperatures range between 9°C in June and 24°C in January [53, 54]. Prevailing winds are southeasterly, with wind speeds of between 11 and 17 km per hour [50].

Vegetation communities in GNP can be broadly categorised into three macro groups namely the mopane, miombo and alluvial woodlands. The majority of major mopane dominated plant communities in GNP have a high capacity to resist drought [55]. However, *Androstachys johnsonni* thicket, *Spirostachys* woodland, *Terminalia prunoides* woodland and streams and pans with *Spirostachys africana* communities have low capacity to resist drought and hence are vulnerable to climate change and variability [55]. Climate-related extreme events have also affected the abundance and phenology of tree species. For instance, tree loss and mortality of many tree species occurred during the 1991–1992 drought [52]. Tafangenyasha [52] suggested that elephant density and drought are probably the major factors that influence tree mortality in Gonarezhou National Park.

The GNP has diverse vertebrate fauna that includes approximately 84 mammal species; 400 bird species; 76 reptile species; 28 amphibian species and 50 fish species. The mammal fauna include 23 large herbivores and 8 carnivore species [50]. The population of browsers/grazers, such as common eland (*Taurotragus oryx,* Pallas, 1766), giraffe, nyala (*Tragelaphus angasii*), waterbuck and wildebeest, are generally low in GNP, whereas elephants, hippopotamus (*Hippopotamus amphibius*), zebra, kudu (*Tragelaphus strepsiceros*) and buffalo (*Syncerus caffer*) are generally high [56]. Large herbivores, such as elephant, buffalo, eland, giraffe, kudu, nyala, waterbuck, zebra, wildebeest and hippopotamus, have a low capacity to resist drought [55]. Extreme events such as drought also directly affect primary productivity and consequently the predator-prey populations. For instance, in GNP, carnivore populations can increase during drought periods, but soon after that, the lack of prey species can lead to aggravated human-wildlife conflict due to overlap between human and wildlife habitats [55].

Drought in particular has caused large herbivore death in GNP during the 1982/1983 and 1991/1992 season [51, 52, 55, 59]. Large mammals, such as elephant, buffalo, hippo and large antelopes, have a low capacity to resist drought [55] and likely to be threatened by climate change [57]. Buffalos in particular are vulnerable to drought [58]. Approximately 1500 elephants died during the 1991–1992 drought [52] and numerous species also suffered significant mortality. Gandiwa [59] investigated the annual rainfall patterns and associated fluctuations of wild large herbivore species data collected from multi-species aerial surveys across five sites in the Great Limpopo Transfrontier Conservation Area (GLTFCA), Southern Africa. Findings from this study suggest that rainfall does have a strong influence on large herbivore population dynamics especially in really dry years in African savannah ecosystems [59]. Using data from aerial surveys, Dunham [39] also assessed the abundance of large herbivores and elephants in GNP for the period between 1980 and 2009. The study revealed that elephant, buffalo, eland, kudu, nyala, waterbuck, wildebeest and zebra generally increased in number, after population declines during the 1992 drought [39].

Drought conditions reduce the available aquatic habitat for water-dependent species such as the hippopotamuses. This 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 [83]. For instance, Zisadza et al. [53] observed an overall decline in common hippopotamus along the Mwenezi and Save River in the GNP (**Figure 2**), primarily to past droughts over the past four decades (e.g. 1982–84 and 1991–92) and other factors such as siltation and persecution in adjacent communal areas. Thus, climate change and variability interact with other stressors to influence the abundance and distribution of wildlife resources.

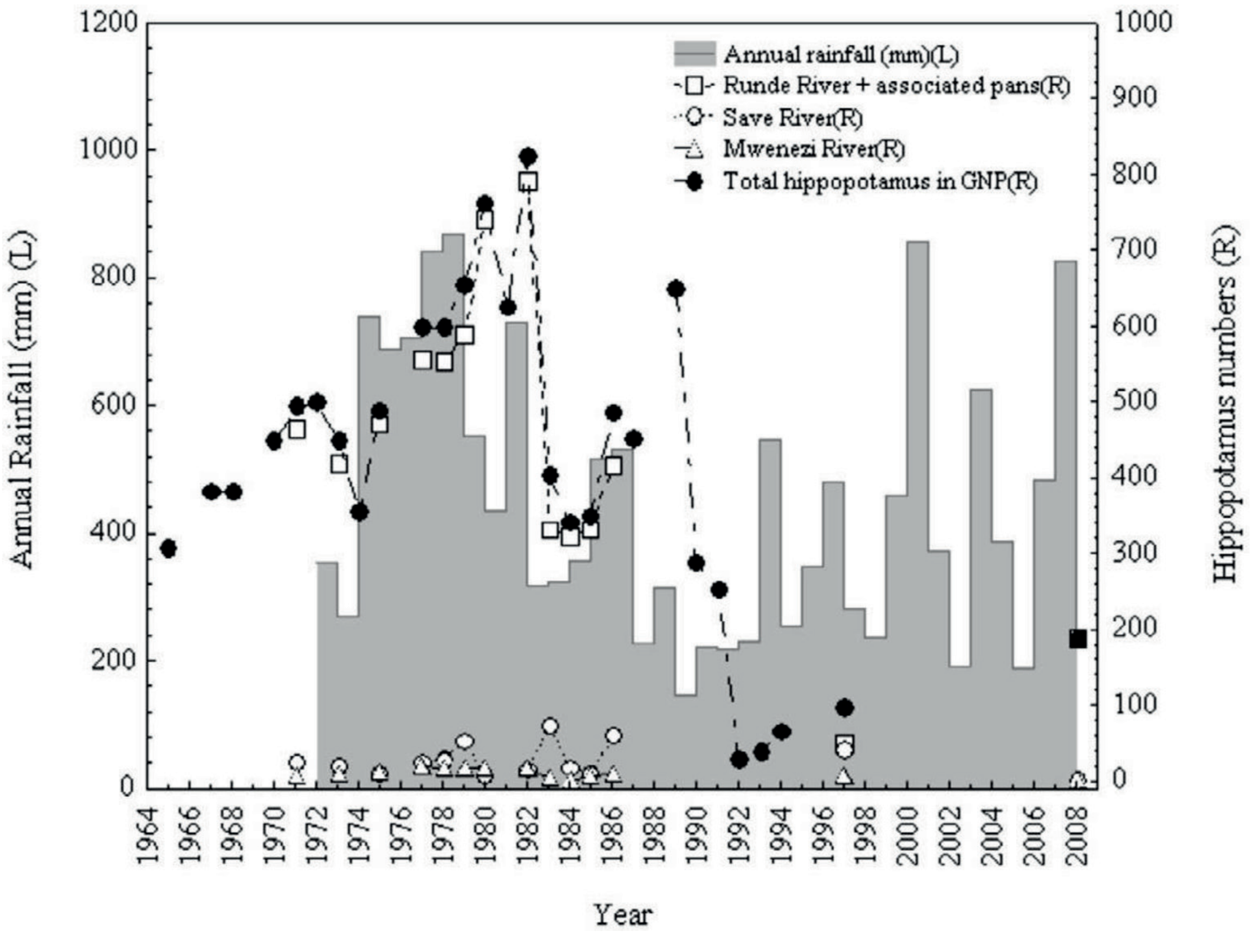

Figure 2. Trends in annual rainfall (1972–2008) and hippo population in the Gonarezhou National Park, Zimbabwe, and its three major rivers for the period 1965–2008. Source: Reproduced with permission from Zisadza et al [53].

Apart from mammals, Gandiwa and Zisadza [55] also noted that water birds, for example pelicans, plovers, storks and fish owls, associated with aquatic habitats such as larger river systems are also under threat from climate change due to reductions in precipitation and resultant changes in the flow regime changes and water holding capacity of water sources.

3.2.2. Case study 2: Mana Pools National Park, Middle Zambezi Valley, Zimbabwe

Mana Pools National Park (MPNP) is located in the Middle Zambezi Valley between (15° 98′ South and 29° 44′ East) and (16° 00′ South and 29° 90′ East) [60]. The park which covers an area of 2196 km^2 was designated a UNESCO World Heritage in 1984 and is also a core area of the Middle Zambezi Biosphere Reserve (MZBR) designated by UNESCO in 2010 [61]. MPNP lies within the proposed Lower Zambezi Mana TFCA. The park is located within the lower Zambezi basin at an altitude of about 350 m within the Zambezi floodplain to about 1100 m over the Zambezi escarpment [60]. Rainfall in the mid-Zambezi valley follows the regional mono-modal pattern with the bulk of the annual average of 706 mm falling between November and March [62]. December and January receive an average of 180 mm each and these two months account for almost half of the annual average in a normal year [63]. Rainfall in MPNP is characterised by monthly and intra-annual variability with a mean annual rainfall of 724 mm [64]. Rainfall variability has a distinct effect on the primary productivity of the area and hence the wildlife that it can support. Average maximum temperatures are 40°C towards the rainy season, whereas mean minimum temperatures are above 10°C [63].

Changes in large herbivore densities have also been reported in the MZBR particularly in the Mana Pools National Park and surrounding communal areas [62]. Climate change induced drought [63] coupled with the closure of floodgates at Kariba Dam and poaching as well as increasing human encroachment into the park [62]. In addition, during the dry season, water availability is restricted to riverine woodlands (**Figure 3**) and a few springs near the escarpment [62].

Apart from seasonal drying up, the quantity and quality of water at some sources have changed (**Figure 3b**, personal observations, 2015) probably due to incessant prolonged drought periods. For example, Chitake spring (**Figure 3a**) near the escarpment is reported to be drying up due to periodic droughts. Aggregation of animals around the springs exerts pressure on forage resources due to over browsing and trampling (**Figure 3b**). For example, Regassa [65] noted that animals tend to aggregate in areas with strategic and scarce resources such as water and pasture in the dry season. In MPNP, inland seasonal water pans (**Figure 4**) and springs also provide water for buffalo herds and other mammals inland.

Studies by Bosongo et al. [66] have shown that the Zambezi Valley is experiencing climate variability and an increase in these events is expected. Rainfall in the middle Zambezi valley is very variable (**Figure 5**) and this could have an effect on the abundance and distribution of large mammals in MPNP. An analysis of the annual rainfall data for Nyamepi shows a high of over 1600 mm in 1978 and a low of slightly above 200 mm in 1974. Large herbivores, in particular, elephant, buffalo, roan, zebra (*Equus quagga*), eland and sable could be under threat

http://dx.doi.org/10.5772/intechopen.70470

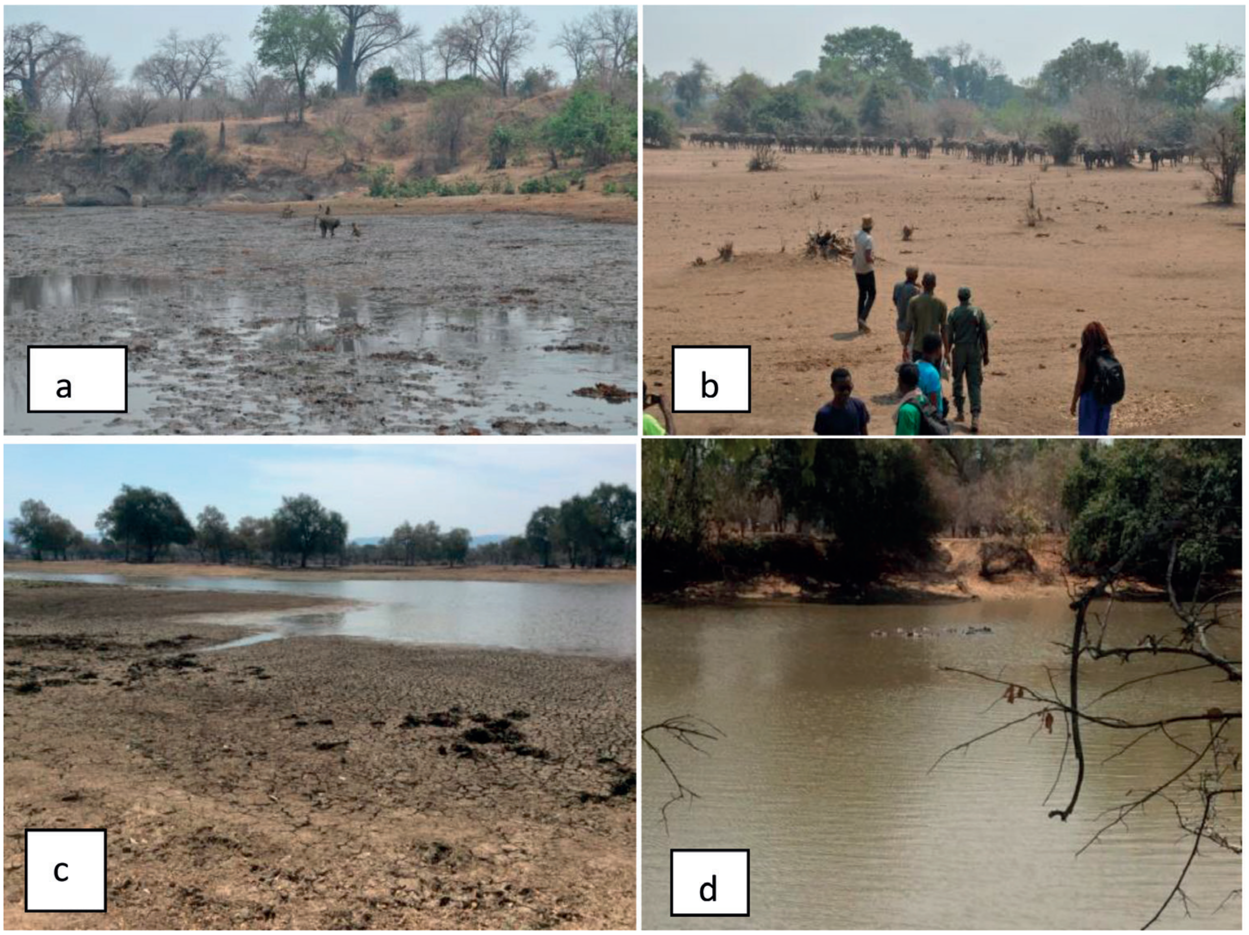

Figure 3. (a) Image of the permanent but dying up Chitake spring near the Zambezi escarpment in MPNP. (b) Buffalo herd aggregate around a permanent but drying natural water source during the drought periods. (c) Natural water pans (Long Pool) close to Nyamepi Camp within the riverine woodlands drying up in October 2015. (d) Image of hippo water bathing along the Long Pool. Photo credit: Olga Laiza Kupika.

Figure 4. Image showing dried up section of Green Pool in MPNP. Photo credit: Olga Laiza Kupika.

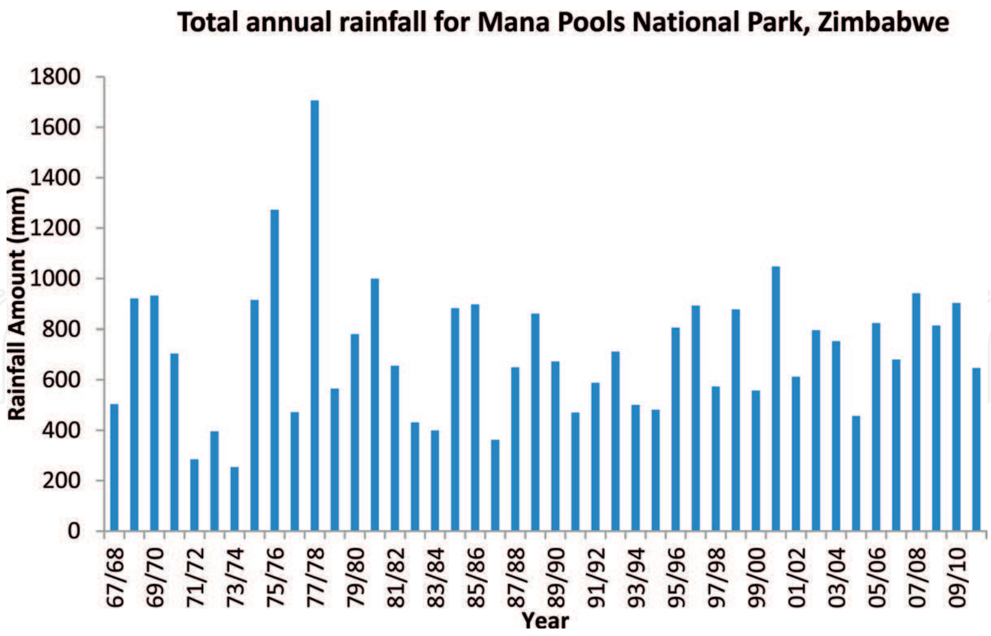

Figure 5. Seasonal rainfall recorded at Nyamepi in Mana Pools National Park, Zimbabwe, located along the Zambezi River for the period 1967–2010. Data are from unpublished records kept at Nyamepi.

from the periodic droughts. Noticeable changes in large mammal populations in the riverine woodlands and adjacent areas due to drought have been observed (**Figure 6**).

An analysis of the annual rainfall data for Nyamepi shows a high of over 1600 mm in 1978 and a low of slightly above 200 mm in 1974. Large herbivores, in particular, elephant, buffalo,

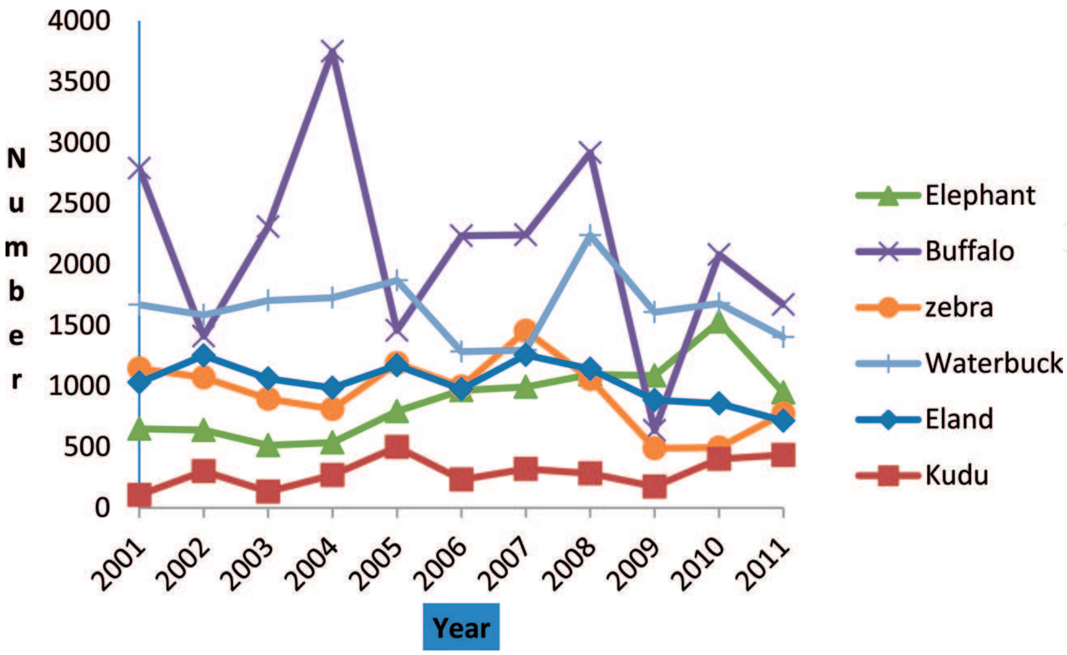

Figure 6. Large herbivore trends in MPNP floodplain (2001–2011). Source: Compiled using secondary data extracted from unpublished reports by research officers of the Department of National Parks and Wildlife Management.

http://dx.doi.org/10.5772/intechopen.70470

roan, zebra (*Equus quagga*), eland and sable could be under threat from the periodic droughts. Noticeable changes in large mammal populations in the riverine woodlands and adjacent areas due to drought have been observed (**Figure 6**).

Although the abundance of selected herbivores in MPNP shows a fluctuating trend (buffalo), there has been a general decline for certain species such as eland and zebra. For example, Dunham [63] observed that between 1982 and 1984, buffalo population within the Zambezi riverine woodlands declined during the drought years due to high mortality and changes in habitat utilization. Macandza et al. [67, 68], Ryan and Wamsley [68] and Megaze et al. [69, 70] also noted that savannah buffaloes moved into riverine habitats during the dry season such that in areas such as Mana Pools National Park, provision of feed supplementation in the floodplain during the dry season could also be attributed to the seasonal increase in buffalo numbers. Additionally, such changes could be attributed to other non-climatic environmental changes within the Zambezi floodplain.

In MPNP, vegetation and other environmental changes have also been observed within the floodplain section partly due to changes in the hydrology of the Zambezi River and periodic droughts [70, 71]. Future studies should focus on monitoring the ecology of the floodplain to promote sustainable utilization or wildlife resources under a changing climate.

3.2.3. Case study 3: Hwange National Park, Zimbabwe

Hwange National Park (HNP), the largest in Zimbabwe, is located on the north-west border of Zimbabwe (19^{1}00°S, 26^{1}30°E) within a semi-arid dystrophic savannah [71, 72, 73]. The elevation of the park ranges between 900 and 1000 m [72, 73]. HNP is located within the Kavango-Zambezi Transfrontier Conservation Area and covers an area of approximately 15,000 km^2 wooded savannah with patches of grassland [33]. The park receives mean annual rainfall of approximately 600 mm with the most rainfall between October and May. Rainfall is generally erratic and unevenly distributed spatially and temporally [72, 73].

Studies by Chamaillé-Jammes et al. [2] revealed that between 1928 and 2005, dry years became even drier and droughts worsening in HNP thereby affecting large herbivore population dynamics. Surface-water availability was strongly influenced by annual rainfall with consequences on large herbivore population dynamics [2]. Drought-related mortality of elephants has also been observed in HNP between 1980 and 1984; 1987 and 1993–1995 prolonged drought period [72]. However, despite the mortalities, rainfall amounts during the 1993–1995 period was higher than the other years [72]. Loveridge et al. [73] carried out a study on the influence of drought on predation of elephant calves by lions (*Panthera leo*) in HNP for the period 1998–2004. The study revealed that high-density aggregations of elephants around limited water sources during the dry season may result in the depletion of local food resources. Additionally, elephant herds were forced to travel long distances between water and forage during which the elephant calves appeared more vulnerable to prey by lions [73, 74].

Crosmary et al. [74, 75] noticed that sable antelope densities declined across the greater HNP region between 1990 and 2001 most probably due to unfavourable rainfall conditions. Crosmary et al. [75, 76] also observed that large herbivores trends particularly selective grazers, generally declined between 1930 and 2000 in HNP and adjacent areas. This decline was attributed to probably greater sensitivity of selective grazers to variation in rainfall compared with other herbivores. During this period, rainfall certainly declined coupled with frequent droughts during the 1990s [75, 76]. Apart from climatic factors, generally large herbivore dynamics in HNP and its surrounding habitats are influenced by surface water provision coupled with other anthropogenic activities such as hunting [2, 75, 76, 77]). Artificial water provision has ecological implications on the structure of vegetation communities and other large herbivores such as elephants [71].

3.3. Climate change adaptation, mitigation, vulnerability and resilience in the wildlife sector

In Southern Africa, adaptation is a major concern in terms of climate change agenda. Climate change adaptation can be defined as the process of taking actions to help communities and ecosystems cope with changing climate conditions [77]. Adaptation can either be reactive in that it can be triggered by historical or current observed climatic events while anticipatory is motivated by the need to respond to future predicted impacts [78, 79]. This implies that wildlife resources have developed short- and long-term mechanisms of coping with the impacts of climate change and variability. Although wildlife has the potential to naturally adapt to the effects of climate change, some scholars contend that the observed and projected effects due to projected climate change might deserve mitigation measures [79, 80]. On the other hand, wildlife managers have also intervened as part of adaptive management either through the manipulation of wildlife habits or wildlife resources in response to the changing climate. Wildlife managers are faced with the daunting task of determining the nature and extent of the wildlife impacts of past climate change and variability [80, 81]. There is therefore need to identify practical strategies that could help to reduce the anticipated effects of climate change on wildlife species [81, 82].

Mitigation is also another area of concern in the context of climate change. Mitigation is defined as interventions to reduce the sources or enhance the sinks of greenhouse gases with the aim of reducing global temperatures. Mitigation measures in the wildlife sector include the adoption of more efficient uses of fossil fuels, the conversion to renewable energies such as solar and wind power and the expansion of forest areas and other sinks to remove greater amounts of carbon dioxide from the atmosphere. If nations worldwide fail to implement such measures, mean global temperatures will continue to increase and the adverse impacts of climate change on societies and economies will worsen.

The Heinz Center [82, 83] carried out extensive literature review that examined information about the ecology and physiology of several megafauna and how each of these species may be vulnerable in the face of climate change and suggested adaptation strategies. The review indicates that there are several key areas of vulnerability, which include the need for surface water; water-dependent; lack of habitat connectivity and heat stress as some of the common vulnerabilities shared across many of the African wildlife species [82, 83]. Mega herbivores, such as the African elephant, black and white rhino and hippopotamus, in particular, are prone to most habitat and species-specific elements of vulnerability [82, 83]. In addition, anthropogenic factors such as illegal harvesting of wildlife resources and poaching also continue to threaten

http://dx.doi.org/10.5772/intechopen.70470

endangered species such as the two rhinoceroses and the African elephant [82]. Climatic and non-climatic factors interact within a social ecological system to influence the vulnerability and resilience of savannah species to climate change. Thus, the capacity of wildlife species to adapt to climate change also depends on their ability to cope with several non-climatic stressors.

The findings from literature reveal that the large carnivore community (lion, leopard, cheetah and wild dogs) is mainly prone vulnerable to disease particularly anthrax and rabies and distemper. For instance, it is observed that climate-related factors in conjunction with other factors,

Strategy	Description
Land and water protection and management	• Increase amount and area covered by Protected Areas • Improve Representation and Replication within Protected-Area Networks • Improve Management and Restoration of Existing Protected Areas to Facilitate Resilience • Design New Natural Areas and Restoration Sites to Maximize Resilience • Protect Movement Corridors, Stepping Stones, and Refugia • Manage and Restore Ecosystem Function Rather than Focusing on Specific Components (Species or Assemblages) • Improve the Matrix by Increasing Landscape Permeability to Species Movement • Reduce non-climate stressors on natural areas and ecosystems
Direct Species Conservation/Management	• Focus Conservation Resources on Species that Might Become Extinct • Translocation or assisted dispersal of species at Risk of Extinction • Establish Captive Populations of Species that Would Otherwise Go Extinct • Reduce Pressures on Species from Sources Other than Climate Change
Monitoring and Planning	• Evaluation of existing monitoring programs for wildlife and key ecosystem components to determine: a) how these programs will need to be modified to provide management-relevant information on the effects of climate change b) what new monitoring systems will need to be established in order to address gaps in our knowledge of climate effects • Incorporate Predicted Climate-Change Impacts into Species and Land-Management Plans, Programs, and Activities • Ensure that wildlife and biodiversity needs are considered as part of the broader societal adaptation process • Develop Dynamic Landscape Conservation Plans
Law and policy review	• Review and Modify Existing Laws, Regulations, and Policies Regarding Wildlife and Natural Resource Management • 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 • Propose new legislation and regulations as needed to provide managers with the flexibility, tools and approaches needed to effectively address climate change impacts

Source: Adopted from Mawdsley et al [81, 82].

Table 2. Strategies for addressing the impacts of climate change on wildlife resources.

such as hunting and disease control impacts by boundary fencing of the park, culling operations and water provisioning, have influenced the dynamics of large herbivore population trends in the Kruger National Park (KNP) over the past century [83, 84]. Thus, the interactive effects of disease and climate-induced factors have the potential to affect many iconic African wildlife species under a changing climate. Changing climatic conditions are therefore likely to affect safari hunting and the wildlife tourism sector due to changes in the abundance of such iconic species.

Mawdsley et al. [81, 82] suggest that effective climate change adaptation incorporates protectionist and interventionist approaches (**Table 2**).

Generally, in Southern Africa, augmenting natural water supplies by providing artificial water points is an intervention commonly adopted by managers of national parks and other large protected areas. In addition, some of the most commonly used adaptation strategies to deal with impacts of climate change in the wildlife sector include:

i. Expansion of protected areas to include migration corridors and seasonal feeding areas [27].

ii. Improving connectivity of habitats to facilitate dispersal to appropriate habitats [27].

In view of the magnitude of impacts, in future it will be important to incorporate predicted and observed climate change impacts into overall wildlife management plans and to review and modify existing laws, regulations and policies regarding wildlife management. Kupika and Nhamo [84] noted that most countries in Southern Africa do not mainstream climate change in their biodiversity-related policies. Thus, lack on enabling policy framework retards progress in as far as responding to climate-related disasters is concerned. Other countries, e.g. Zimbabwe, rely on a centralized system towards disaster risk reduction. Although the implementation on the ground is multi-sectoral, disaster response is hampered by bureaucracy within the Parks and Wildlife Management Authority. Thus, protected area managers are not flexible to directly implement any short-term or long-term adaptation strategies to ensure improved species conservation.

Apart from mainstreaming enabling laws and regulations, consideration should also be given to managing protected areas for climate change mitigation through carbon storage and sequestration, as well as for other ecosystem services. Despite all efforts to adapt to the changing climate, efforts are hampered by several factors related to technical and financial constraints to implement the strategies. Africa as a continent is highly vulnerable to the impacts of climate change because of other multiple stressors such as poverty; illiteracy and lack of skills; weak institutions; lack of political will to confront climate change challenges; limited infrastructure; lack of technology and information; poor health care; armed conflicts; rampant corruption and host of other human anthropogenic activities [13]. Thus, managing threats to the wildlife resources consequently include managing other confounding stressors to biodiversity.

4. Conclusion

Generally, climate-induced extreme events such as prolonged and frequent drought periods influenced the abundance and distribution of wildlife resources across Southern

Africa. In addition, temperature related extreme events such as heat waves also threaten the ecology of heat sensitive species. Thus wildlife resources are under threat from the confounding effects of rainfall and temperature changing climate. The abundance of both flora and fauna is influenced by the interactive effects of climate change and other non-climatic multiple stressors. Wildlife species have different levels of vulnerability and resilience to climate change induced impacts. Stakeholders in the wildlife sector are therefore faced with a task to continuously monitor wildlife resources under a changing climate. Since responses of wildlife resources to climate variability and change are both location- and species-specific [85] protected area managers should come up with different strategies to mitigate the impacts of climate change on vulnerable habitats and specific species depending on their ecology.

Acknowledgements

This work was conducted within the framework of the Research Platform "Production and Conservation in Partnership (HYPERLINK "http://www.rp-pcp.org" www.rp-pcp.org). This research was supported by funding from the European Union under the Delivering Innovation and technology through the Reinforcement of Agricultural and Multidisciplinary research capacity (DREAM) project & the Chinhoyi University of Technology (CUT), Zimbabwe.

Author details

Olga L. Kupika[1]*, Edson Gandiwa[1], Shakkie Kativu[2] and Godwell Nhamo[3]

*Address all correspondence to: olgal.kupika@gmail.com

1 Department of Wildlife Ecology and Conservation, Chinhoyi University of Technology, Chinhoyi, Zimbabwe

2 Department of Biological Sciences, Faculty of Science, University of Zimbabwe, Harare, Zimbabwe

3 Institute for Corporate Citizenship, University of South Africa, Pretoria, South Africa

References

[1] Dawson TP, Jackson ST, House JI, Prentice IC, Mace GM. Beyond predictions: Biodiversity conservation in a changing climate. Science (80-). 2011;**332**:53-58

[2] Chamaillé-Jammes S, Fritz H, Murindagomo F. Climate-driven fluctuations in surface-water availability and the buffering role of artificial pumping in an African savanna: Potential implication for herbivore dynamics. Austral Ecology. 2007;**32**:740-748

[3] IPCC. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. IPCC, Geneva; 2007. pp. 1-976

[4] AMCEN Secretariat. Addressing Climate Change Challenges in Africa; A Practical Guide Towards Sustainable Development. Addis Ababa, Ethiopia: African Union; 2011. p. 272

[5] IPCC. Climate Change and Biodiversity. IPCC Technical Paper V Group. 2002;**24**:77

[6] IPCC. Climate Change: Synthesis Report Summary Chapter for Policymakers. IPCC; Geneva; 2014. p. 31

[7] Wilsey CB, Lawler JJ, Freund JA, Hagmann K, Hutten KM, Sciences F, Wildland P, Sciences F, Street N. Tools for Assessing Climate Impacts on Fish and Wildlife. Journal of Fish and Wildlife Management. 2013;**4**:220-241

[8] Yarrow G. Wildlife and Wildlife Management. Clemson Extension; 2009. p. 2

[9] Collier P, Conway G, Venables T. Climate change and Africa. Oxford Review of Economic Policy. 2008;**24**:337-353

[10] Ntuli H, Muchapondwa E. A bio-economic analysis of community wildlife conservation in Zimbabwe. Journal for Nature Conservation. 2015;**37**:106-121

[11] Barker T. IPCC (Intergovernmental Panel on Climate Change) Climate Change 2007: An Assessment of the Intergovernmental Panel on Climate Change; 2007. p. 12-17

[12] IPCC. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva; 2014

[13] IPCC. Climate Change 2007: Impacts, adaptation and vulnerability: Working Group II contribution to the Fourth Assessment Report of the IPCC Intergovernmental Panel on Climate Change; Geneva; 2007. p. 976

[14] IPCC. Summary for Policymakers. Climate Change 2014: Impacts, Adaptation, and Vulnerability—Contribution of Working Group II to the Fifth Assessment Report; Geneva; 2014. p. 1-32

[15] IPCC. Summary for Policymakers. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; Geneva; 2014. p. 1-32

[16] Alig JR. Effects of Climate Change on Natural Resources and Communities: A Compendium of Briefing Papers; 2011. p. 169

[17] Solomon S. Climate Change 2007—The Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC. Vol. 4. Cambridge University Press; 2007

[18] Diffenbaugh NS, Field CB. Changes in ecologically critical terrestrial climate conditions. Science (80). 2013;**341**:486-492

[19] Texeira M, Baldi G, Paruelo J. An exploration of direct and indirect drivers of herbivore reproductive performance in arid and semi arid rangelands by means of structural equation models. Journal of Arid Environment. 2012;**81**:26-34

[20] Milligan SR, Holt WV, Lloyd R. Impacts of climate change and environmental factors on reproduction and development in wildlife. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences. 2009;**364**:3313-3319

[21] Koons DN, Terletzky P, Adler PB, Wolfe ML, Ranglack D, Howe FP, Hersey K, Paskett W, du Toit JT. Climate and density-dependent drivers of recruitment in plains bison. Journal of Mammalogy. 2012;**93**:475-481

[22] Forrest JL, Wikramanayake E, Shrestha R, Areendran G, Gyeltshen K, Maheshwari A, Mazumdar S, Naidoo R, Thapa GJ, Thapa K. Conservation and climate change: Assessing the vulnerability of snow leopard habitat to treeline shift in the Himalaya. Biological Conservation. 2012;**150**:129-135

[23] Molnar PK, Derocher AE, Thiemann GW, Lewis MA. Predicting survival, reproduction and abundance of polar bears under climate change. Biological Conservation. 2010;**143**:1612-1622

[24] Shrader AM, Pimm SL, van Aarde RJ. Elephant survival, rainfall and the confounding effects of water provision and fences. Biodiversity and Conservation. 2010;**19**:2235-2245

[25] Saba VS, Stock CA, Spotila JR, Paladino FV, Tomillo PS. Projected response of an endangered marine turtle population to climate change. Nature Climate Change. 2012;**2**:814-820

[26] Advani N. Mountain gorilla WWF Wildlife and Climate Change Series. 2014. 4 pp

[27] Chidumayo E, Okali D, Kowero G, Larwanou M, editors. Climate Change and African Forest and Wildlife Resources. Nairobi, Kenya: African Forest Forum; 2011. p. 252

[28] Levina E, Tirpak D. Adaptation to Climate Change: Key Terms. Organisation for Economic Co-operation and Development; 2006. p. 1-25

[29] Ogutu JA, Owen-Smith RN. ENSO, rainfall and temperature influences on extreme population declines among African savannah ungulates. Ecology Letters. 2003;**6**:412-419

[30] Owen-Smith N, Mason DR, Ogutu JO. Correlates of survival rates for 10 African ungulate populations: Density, rainfall and predation. The Journal of Animal Ecology. 2005;**74**:774-788

[31] Reid, H. and Swiderska, K. Biodiversity, Climate Change and Poverty: Exploring the Links. IIED Briefing. 2008. 6 pp

[32] Simmons RE, Barnard P, Dean W, Midgley GF, Thuiller W, Hughes G. Climate change and birds: perspectives and prospects from Southern Africa. Ostrich. 2004;**75**:295-308

[33] Chamaille-Jammes S, Fritz H, Murindagomo F. Spatial patterns of the NDVI–rainfall relationship at the seasonal and interannual time scales in an African savanna. International Journal of Remote Sensing. 2006;**27**:185-200

[34] Washington R, Preston A. Extreme wet years over Southern Africa: Role of Indian Ocean sea surface temperatures. Journal of Geophysical Research – Atmospheres. 2006;**111**:1-15

[35] Davis CL. Climate Risk and Vulnerability: A Handbook for Southern Africa. Pretoria, South Africa: Council for Scientific and Industrial Research; 2011. p. 92

[36] Berteaux, D, de Blois S, Angers J F, Bonin J, Casajus N, Darveau M, Fournier F, Humphries M M, McGill B, Larivée J, Logan T, Nantel P, Périé C, Poisson F, Rodrigue D, Rouleau S, Siron R, Thuiller W and Vescovi L 2010 The CC-Bio project: Studying the effects of climate change on Quebec biodiversity. Diversity. **2**:1181-1204

[37] Gandiwa E. Vegetation factors influencing density and distribution of wild large herbivores in a southern African savannah. African Journal of Ecology. 2014;**52**:274-283

[38] Tokolyi J, Schmidt J, Barta Z. Climate and mammalian life histories. Biological Journal of the Linnean Society. 2014;**111**:719-736

[39] Dunham KM. Trends in populations of elephant and other large herbivores in Gonarezhou National Park, Zimbabwe, as revealed by sample aerial surveys. African Journal of Ecology. 2012;**50**:476-488

[40] Du Toit JT, Biggs H, Rogers KH. The Kruger Experience: Ecology and Management of Savanna Heterogeneity; 2003. p. 519

[41] Ogutu JO, Owen-Smith N, Piepho HP, Said MY. Continuing wildlife population declines and range contraction in the Mara region of Kenya during 1977-2009. Journal of Zoology. 2011;**285**:99-109

[42] Fritz H, Duncan P. On the carrying capacity for large ungulates of African savanna ecosystems. Proceedings of the Biological Sciences. 1994;**256**:77-82

[43] Muthoni FK, Groen TA, Skidmore AK and van Oel P. 2014. Ungulate herbivory overrides rainfall impacts on herbaceous regrowth and residual biomass in a key resource area. Journal of Arid Environments. **100-101**:9-17

[44] Riginos C. Climate and the landscape of fear in an African savanna. The Journal of Animal Ecology. 2015;**84**:124-133

[45] Wigley BJ, Fritz H, Coetsee C, Bond WJ. Herbivores shape woody plant communities in the kruger national park: Lessons from three long-term exclosures. Koedoe. 2014;**56**:1-12

[46] Ogutu JO, Piepho HP, Dublin HT, Bhola N, Reid RS. Rainfall influences on ungulate population abundance in the Mara-Serengeti ecosystem. Journal of Animal Ecology. 2008;**77**(4):814-829

[47] Dixon RK, Smith J, Guill S. Life on the edge: Vulnerability and adaptation of African ecosystems to global climate change. Mitigation and Adaptation Strategies for Global Change. 2003;**8**:93-113

[48] Ogutu JO, Piepho H-P, Kanga E. Dynamics of an insularized and compressed impala population: rainfall, temperature and density influences. Open Ecology Journal. 2012;**5**:1-17

[49] IPCC. Cambio climático 2014. Impactos, adaptación y vulnerabilidad—Resumen oara responsables de políticas. Contrib. del Grup. Trab. II al Quinto Inf. Evaluación del Grup. Intergub. Expert. sobre el Cambio Climático; Geneva; 2014. p. 34

[50] Zimbabwe Parks and Wildlife Management Authority [ZPWMA]. Gonarezhou National Park General Management Plant 2011-2021, Harare, Zimbabwe. 2011

[51] Gandiwa E, Magwati T, Zisadza P, Chinuwo T, Tafangenyasha C. The impact of African elephants on Acacia tortilis woodland in northern Gonarezhou National Park, Zimbabwe. Journal of Arid Environments. 2011;**75**:809-814

[52] Tafangenyasha C. Tree Loss in Gonarezhou National Park (Zimbabwe) between 1970 and 1983. Journal of Environmental Management. 1997;**3**:355-366

[53] Zisadza P, Gandiwa E, Der WHV, Van E, Westhuizen D, Bodzo V, Zisadza P, Gandiwa E, Der WHV, Der WEV, Bodzo V. Abundance, distribution and population trends of hippopotamus in Gonarezhou National Park, Zimbabwe. South African Journal of Wildlife Research. 2010;**40**:149-157

[54] Gandiwa E, Kativu S. Influence of fire frequency on *Colophospermum mopane* and *Combretum apiculatum* woodland structure and composition in northern Gonarezhou National Park, Zimbabwe. Koedoe. 2009;**51**:1-13

[55] Gandiwa E, Zisadza P. Wildlife management in Gonarezhou National Park, Southeast Zimbabwe: Climate change and implications for management. Nature and Faune. 2010;**25**:96-106

[56] Dunham KM, Van Der Westhuizen E, Van Der Westhuizen H F, Gandiwa E. Aerial Survey of Elephants and other Large Herbivores in Gonarezhou National Park (Zimbabwe), Zinave National Park (Mozambique) and surrounds: 2009. 2010

[57] Magadza CHD. Magadza 2000.pdf. Environmental Monitoring and Assessment. 2000;**61**: 193-205

[58] Scholte P. Towards understanding large mammal population declines in Africa's protected areas: A West-Central African perspective. Tropical Conservation Science. 2011;**4**:1-11

[59] Gandiwa E. Rainfall variability and its impact on large mammal populations in a complex of semi-arid African savanna protected areas. Tropical Ecology. 2016;**57**:163-180

[60] Muposhi VK, Muvengwi J, Gandiwa E, Chinake N, Muboko N, Maponga T, Kuvaoga P, Maponga T. Vegetation characteristics of white-browed sparrow weaver nesting sites in Mana Pools. Journal of Biodiversity Management & Forestry. 2015;**4**:2-7

[61] UNEP. Mana Pools National Park, Sapi and Chewore Safari Areas, Harare, Zimbabwe. 1984

[62] Zimbabwe Parks and Wildlife Management Authority [ZPWMA]. Mana Pools National Park General Management Plan Part 2 : Background. Harare, Zimbabwe. 2009. pp. 104

[63] Dunham KM. The effect drought on the large mammal populations of Zambezi riverine woodlands. Zoological Society of London. 1994;**234**:489-526

[64] Dunham KM, du Toit A J. Using citizen-based survey data to determine densities of large mammals: A case study from Mana Pools National Park, Zimbabwe. African Journal of Ecology. 2013;**51**:431-440

[65] Regassa R. Distribution, abundance and population status of Burchells zebra (*Equus quagga*) in Yabello Wildlife Sanctuary, Southern Ethiopia. Journal of Ecology and the Natural Environment. 2013;**5**:40-49

[66] Bosongo GB, Longo JN, Goldin J, Muamba VL. Socioeconomic impacts of floods and droughts in the middle Zambezi river basin. International Journal of Climate Change Strategies and Management. 2014;**6**:131-144

[67] Macandza VA, Owen-Smith N, Cross PC. Forage selection by African buffalo in the late dry season in two landscapes. South African Journal of Wildlife Research-24-month delayed open access. 2004;**34**(2):113-121

[68] Ryan RL, Wamsley MB. Perceptions of wildfire threat and mitigation measures by residents of fire-prone communities in the Northeast: survey results and wildland fire management implications. 2006

[69] Megaze A, Balakrishnan M, Belay G. Diurnal activity budget of African buffalo (Syncerus caffer Sparrman, 1779) in Chebera Churchura National Park, Ethiopia. African Journal of Ecology. 2016

[70] Ncube S, Beevers L, Hes EMA. The Interactions of the Flow Regime and the Terrestrial Ecology of the Mana Floodplains in the Middle Zambezi River Basin. Ecohydrology; 2012

[71] Chamaillé-Jammes S, Valeix M, Fritz H. Managing heterogeneity in elephant distribution: interactions between elephant population density and surface-water availability. Journal of Applied Ecology. 2007;**44**(3):625-633

[72] Dudley JP, Criag GC, Gibson D, Haynes G, Klimowicz J. Drought mortality of bush elephants in Hwange National Park, Zimbabwe. African Journal of Ecology. 2001;**39**(2):187-194

[73] Loveridge AJ, Hunt JE, Murindagomo F, Macdonald DW. Influence of drought on predation of elephant (*Loxodonta africana*) calves by lions (*Panthera leo*) in an African wooded savannah. Journal of Zoology. 2006;**270**:523-530

[74] Crosmary WG, Chamaillé-Jammes S, Mtare G, Fritz H, Côté SD. Decline of sable antelope in one of its key conservation areas: The greater Hwange ecosystem, Zimbabwe. African Journal of Ecology. 2015;**53**(2):194-205

[75] Crosmary WG, Côté SD, Fritz H. Does trophy hunting matter to long-term population trends in African herbivores of different dietary guilds? Animal Conservation. 2015;**18**:117-130

[76] Chamaillé-Jammes S, Charbonnel A, Dray S, Madzikanda H, Fritz H. Spatial distribution of a large herbivore community at waterholes: An assessment of its stability over years in Hwange National Park, Zimbabwe. PLoS One. 2016;**11**:1-13

[77] Chong J. Ecosystem-based approaches to climate change adaptation: progress and challenges. International Environmental Agreements: Politics, Law and Economics. 2014;**14**:391-405

[78] Osbahr H, Twyman C, Adger W, Thomas D. Evaluating successful livelihood adaptation to climate variability and change in Southern Africa. Ecology and Society. 2010;**15**(2)

[79] Sheikh PA, Corn ML, Leggett JA, Folger P. Global Climate Change and Wildlife. Annual Review of Ecology, Evolution, and Systematics. 2006;**37**:637-669

[80] Prato T. Evaluating and managing wildlife impacts of climate change under uncertainty. Ecological Modelling. 2009;**220**:923-930

[81] Mawdsley JR, O'Malley R, Ojima DS. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology. 2009;**23**:1080-1089

[82] The Heinz Center. Climate-Change Vulnerability and Adaptation Strategies for Africa's Charismatic Megafauna. Washington, DC, The H. John Heinz III Center for Science, Economics and the Environment; 2012

[83] Owen-Smith N. Spatial ecology of large herbivore populations. Ecography (Cop.). 2014;**37**:416-430

[84] Kupika OL, Nhamo G. Mainstreaming biodiversity and wildlife management into climate change policy frameworks in selected east and southern African countries. Jàmbá: Journal of Disaster Risk Studies. 2016;**8**(3):1-9

[85] Thompson ID. An overview of the science–policy interface among climate change, biodiversity, and terrestrial land use for production landscapes. Journal of Forest Research. 2015;**20**(5):423-429