

# The Impact of Climate Change on the Conservation and Survival of the Cheetah

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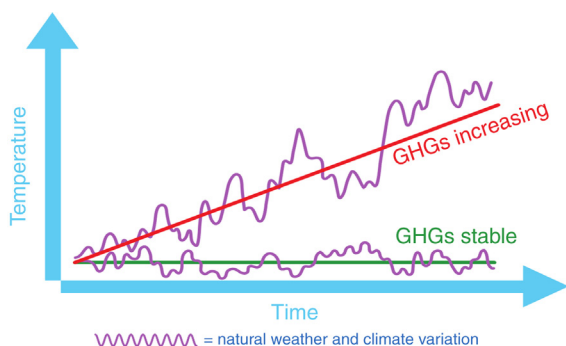
## INTRODUCTION

### Global Warming and the Cheetah

Current global warming, which multiplies all historic threats to cheetah persistence (Durant et al., 2015; Marker, 2002; Chapters 10, 11, 13, and 14), is caused by human interference with earth's energy balance (Schneider, 1989). Incoming shortwave radiation from the sun ultimately must be balanced by the outgoing long-wave radiation emitted back into space from the earth and its atmosphere (Lutgens and Tarbuck, 2004). A climate forcing is a factor that perturbs this balance (Hansen and Sato, 2004). For example,

aerosols (small particles that become suspended in the atmosphere) released by volcanoes or human industrial activities can provide a <1–2 years negative (cooling) forcing, by reflecting the sun's energy back into space before it reaches earth's surface. Increased concentrations of CO<sub>2</sub>, methane, and other greenhouse gases (GHGs) provide a positive (warming) forcing, prolonging retention of the sun's energy before it escapes back into space. Unlike aerosols, GHGs persist in the atmosphere for decades to centuries.

Natural climate fluctuations (e.g., El Niño, La Niña) are independent of anthropogenic climate forcings, and make some periods cooler and



**FIGURE 12.1** General relationship between temperature and time, with and without persistent greenhouse gas (GHG) forcing. With GHG levels stable, the average of natural climate fluctuations is a level line (green). But with rising GHG levels, average temperatures must rise (red). Despite the chaotic and unpredictable nature of natural variations (purple lines), it always will be warmer than it would have been without the higher GHG concentration. *Source: Designed by S.C. Amstrup, graphic by Peppermint Narwhal.*

others warmer than average (Deser et al., 2012). In the natural state where GHG concentrations are stable, the long-term average or “baseline” around which these oscillations occur can be represented as a horizontal line. With chronically increasing GHG forcing, natural fluctuations in the climate system will continue, but over a higher and rising baseline (Fig. 12.1).

Existing GHG emission patterns have multicentennial and even millennial ramifications. Avoiding centennial climate change milestones, however, is critical to preserve cheetahs and their habitats in those longer terms. Therefore, we focus on climate change thresholds that, without GHG mitigation, are likely to be exceeded by the latter 21st century. As global warming is primarily caused by human activities in the industrialized world, cheetah conservation depends on societies, distant from cheetahs, adopting sustainable economies based on renewable energy sources. Here, we describe climate change symptoms of warming that have the potential to determine the cheetah’s future, and we summarize on-the-ground conservation actions that will maximize the potential for cheetahs to persist under a changing global climate.

## Climate Change: Temperature and Precipitation

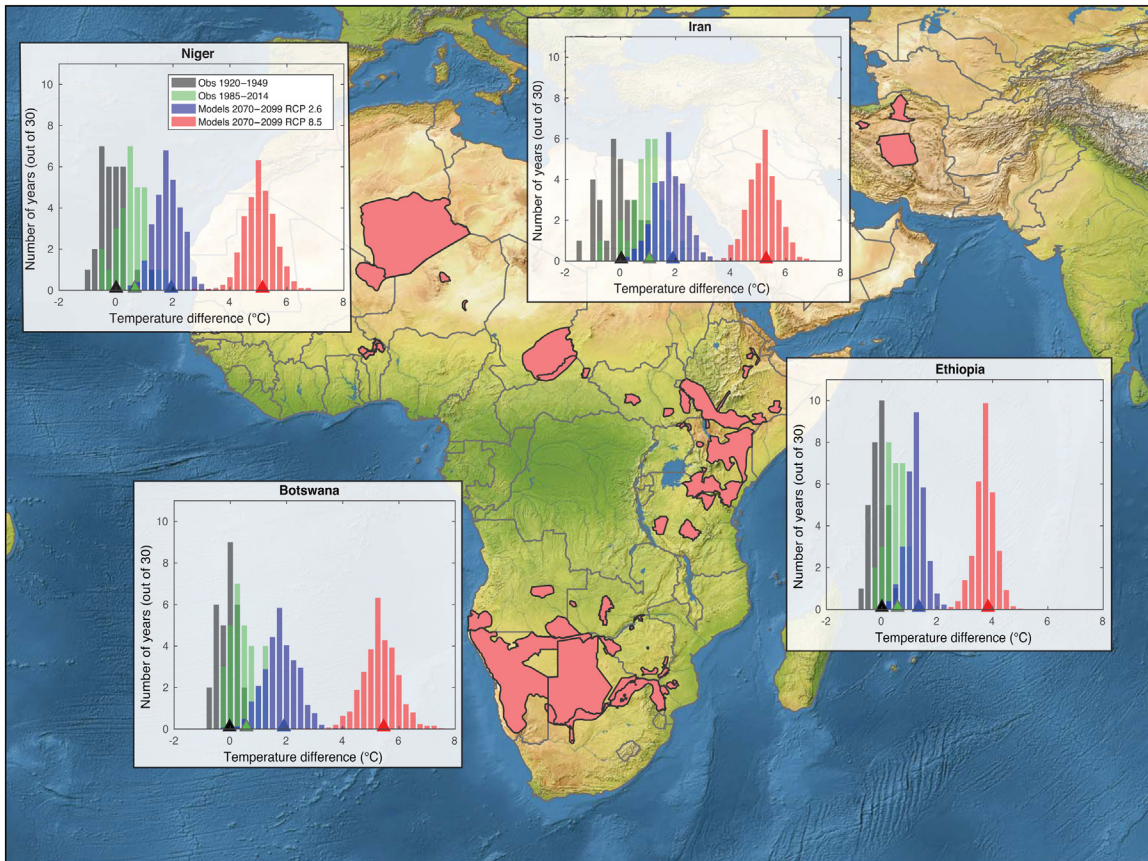
Although global warming is indeed global, different regions will warm at different rates, and they may experience differing climate change symptoms at different times. Within the mostly arid remaining range of cheetahs (portions of southern, central, and northern Africa, and Iran; Chapters 4 and 5), the biggest climate change concerns are related to increasing temperatures and changing precipitation patterns. Across the cheetah’s current range, average temperatures have increased between 1 and 2°C, since the early part of the 20th century (Fig. 12.2). Following current GHG emissions [Representative Concentration Pathway 8.5 (RCP 8.5); Wayne, 2013] another ~3°C warming is likely by the end of this century. However, aggressive GHG mitigation (RCP 2.6) could limit additional average temperature rise to between 1 and 2°C (Fig. 12.2).

Precipitation changes are more difficult to predict. Globally, more precipitation is assured because warmer air holds more water vapor, but the distribution of precipitation is spatially heterogeneous. Observations of recent decades show that some historically wet areas have become wetter, and dry areas have become drier as the world has warmed (Greve et al., 2014). This pattern is projected to continue with further warming (Durack et al., 2012; Held and Soden, 2006). In addition to altered average moisture distribution, frequencies of droughts, floods, and generally extreme weather are expected to increase (National Academies of Sciences, Engineering, and Medicine, 2016).

### IMPACTS OF INCREASING TEMPERATURES AND ALTERED PRECIPITATION

#### Water Availability

In response to increased temperatures and changes in the hydrologic cycle, surface water availability in most of the cheetah’s range will



**FIGURE 12.2** Annual mean temperature anomalies ( $^{\circ}\text{C}$ ) in each of the four geographic regions where cheetahs occur, as represented by data from Niger (west Africa), Ethiopia (East Africa), Botswana (southern Africa), and Iran. For each region, three 30-year periods (historical: 1920–1949 and 1985–2014; and two projections for: 2070–2099), are represented. The number of years for which the annual mean temperature differs from the mean temperature recorded in 1920–1949, is shown. Triangles represent the average for each of the 30 year periods. The Representative Concentration Pathway (RCP) 8.5, or "business as usual," projection assumes GHG emissions will continue unabated at the present-day rate. The RCP 2.6 projection assumes dramatic reductions of GHG emissions over the course of this century, with a chance of keeping global mean temperature rise below  $2^{\circ}\text{C}$ . Data for historical and current periods are based on gridded temperature observations from the Berkeley Earth Surface Temperature dataset (Rohde et al., 2013). The two different projections for the late 21st century, 2070–2099, are based on the multimodel mean of 25 climate models of the 5th Coupled Model Intercomparison Project (CMIP5; Taylor et al., 2012). Source: Cheetah distribution data from Durant, et al., 2017. Graphic by S.C. Amstrup and D.C. Douglas

become more limited. Increased drought frequency is expected to accompany declines in average water availability. For example, Iran, home of the most threatened population of cheetahs (Chapter 5), where the historic mean annual precipitation base is ~250 mm, has seen dramatic declines in moisture over much of the country (Amiri and Eslamian, 2010). Lake Urmia, historically the largest lake in the Middle East, and a critical water source for Iran's agriculture, has lost 88% of its surface area since the 1970s (Mirchi et al., 2015). In southern Africa, at the opposite end of the cheetah distribution, unusually dry spells became more frequent and wet spells less so after the 1960s (Garanganga, 2011). The 1981–1983 drought in southern Africa directly and indirectly impacted agriculture, wildlife, and human livelihoods (Garanganga, 2011; Hillman and Hillman, 1977; Klein, 2006; Marker-Kraus et al., 1996; Verlinden, 1997). As temperatures increased over the last 60 years, frequencies of intense rains and widespread drought increased in Namibia (Turpie et al., 2010), and estimated water balance declined at 1/3 of water monitoring stations. Heat waves in the southern part of Africa are projected to increase 3.5-fold over current conditions while drought frequency increases (Lyon, 2009).

Lyon and DeWitt (2012) reported that a clear decline in East African precipitation beginning in the 1980s accelerated after 1999. Average precipitation in the Sahel and Greater Horn of Africa decreased when comparing the mean of 1990–2009 to that of 1970–1989 (Williams et al., 2012). The higher drought frequency and more pulsatile precipitation observed in recent decades across southern and eastern Africa are projected to increase (Funk et al., 2012; Garanganga, 2011; Williams and Funk, 2011). Projections of reduced rainfall and increased frequency of prolonged droughts where the climate historically has been arid to semiarid (Omari, 2010) can only exacerbate recently observed problems.

## Altered Habitat

Some woody plants are more drought-tolerant and efficient than grasses in utilizing the elevated atmospheric CO<sub>2</sub> (Higgins and Scheiter, 2012; MET, 2008), and woody plants are already invading much of the open savannah habitat that cheetahs prefer (Muntifering et al., 2006). This “bush encroachment”, occurring across varying land use practices, has been attributed to warmer and drier conditions and increased atmospheric CO<sub>2</sub> concentrations (Wigley et al., 2009, 2010). Midgley et al. (2005) projected that with current GHG emission trends, Namibian savanna habitats will decline 22%–67% by the latter part of the century, while desert habitats and shrublands were projected to increase by 27%–45% and 14%–18%. Although harvesting shrubs to produce sources of alternative energy (e.g., Cheetah Conservation Fund's Bushblok program) and other habitat restoration programs have emerged, they are unlikely to keep up with the accelerated habitat alterations of the future (Higgins and Scheiter, 2012; MET, 2008). Bush encroachment reduces visibility, which may affect the hunting efficiency of cheetahs, and lowers densities of the cheetah's preferred open habitat prey species like eland (*Tragelaphus oryx*), oryx (*Oryx gazella*), red hartebeest (*Alcelaphus buselaphus*), and warthog (*Phacochoerus africanus*) (Marker, 2002; Muntifering et al., 2006).

## Parasites and Disease

As livestock and wildlife both aggregate at water points, especially during the dry seasons, disease transfer between livestock and wildlife is likely to increase as temperature rises and water becomes more scarce. In addition, the projected higher frequency of alternating drought and flood periods may create favorable conditions for arthropod disease vectors, such as ticks and fleas (Roach, 2008; Sejian et al., 2016). Olwoch et al. (2008) reported a range shift and

expansion in some southern African countries of the tick *Rhipicephalus appendiculatus* in response to the temperature and rainfall changes. This tick is a vector for Theileriosis (East Coast fever), a disease causing livestock industry losses of US \$168 million annually (Norval et al., 1992; Olwoch et al., 2008). Other serious tick-borne diseases include African swine fever, transmitted by the tick *Ornithodoros moubata* and mostly carried by warthogs. Heartwater, a tick-borne rickettsial disease of ruminants, including eland and springbok (*Amphipneustes marsupialis*), is caused by the tick *Amblyomma hebraeum*.

Despite the anticipated drying of most cheetah habitats, canine distemper virus (CDV) could become an increased problem. Outbreaks of feline infections with CDV in the Serengeti ecosystem were linked to climate change in 1994 and 2001, with losses of up to 1/3 of lions (*Panthera leo*) in the area (Munson et al., 2005; Roach, 2008; Roelker-Parker et al., 1996). Prevalence of CDV antibodies among the free-ranging Namibian cheetah population is confirmed (Munson et al., 2005), although low population densities, large territories, and dry environments apparently keep infection rates low (Marker, 2002).

Alternating droughts and heavy rains also drive pathogenic outbreaks of anthrax (Hampson et al., 2011; Lelenguyah, 2012), a disease to which cheetahs are highly susceptible (Good et al., 2008; Jäger et al., 1990; Lembo et al., 2011; Switzer et al., 2016; Turnbull et al., 2004). In southern and eastern Africa, anthrax is well documented in cheetah prey species (Hampson et al., 2011), and deaths from anthrax have been documented in wild and captive cheetahs in Namibia and Botswana (Good et al., 2008; Jäger et al., 1990; Switzer et al., 2016). Impacts of anthrax and other diseases on survival of free-ranging cheetahs in a hotter drier and more unpredictable environment are as of yet largely unknown, but certainly cause for concern.

## Conflicts with Humans

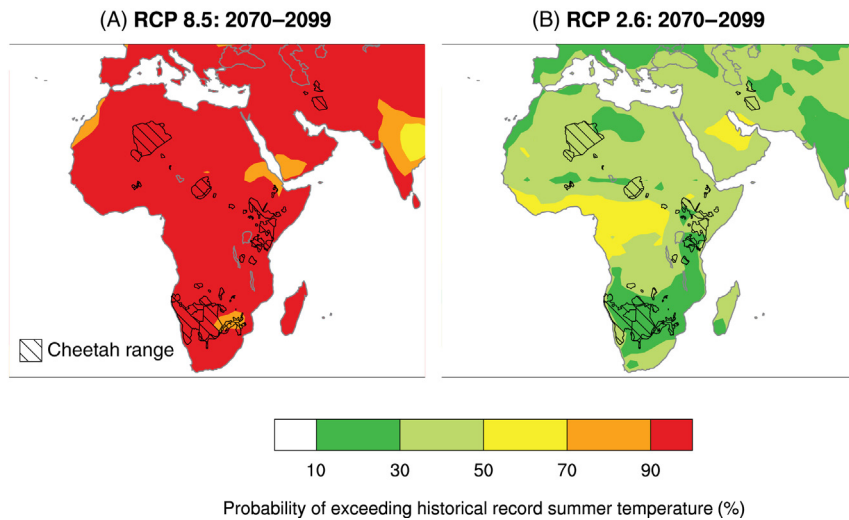
Escalating conflicts between humans and cheetahs are virtually assured in a warming world (Marker et al., 2008), even if human numbers were to remain stable. At the height of the 1980s drought, for example, approximately 890 Namibian cheetahs were captured or killed annually due to escalated conflict with livestock farmers (Marker-Kraus et al., 1996). Growing human populations exacerbate such conflicts. In southern African cheetah range countries, the human population of 144.49 million is projected to increase by a factor of 1.8 by 2050 and triple by century's end. Similar increases in human numbers are expected across most of the cheetah's range (The World Bank, 2016). At the same time, both predators and natural prey will need to search larger landscapes for food and water, while human food and water stresses increase (Asseng et al., 2014; Liu et al., 2016).

With rapid human population growth, increases in poaching, deforestation, and other land conversions will magnify declines in habitat (Chapter 10) and wildlife security (Chapter 11) resulting from a warming climate. As wildlife have greater ability to adapt to limited moisture distribution than livestock (Marker-Kraus et al., 1996), game farming has increased in drought periods and may further gain in popularity as drought frequencies rise. Often accompanied by 2.5-m-high fences, game farms can restrict normal wildlife movements restricting cheetah access to habitat and prey (Marker-Kraus et al., 1996; Marker et al., 2003; Schumann et al., 2008), at the same time landowner disputes over wildlife ownership are likely to increase (Marker-Kraus et al., 1996).

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## DISCUSSION

Effects of observed 20th century warming across the cheetah's range are harbingers of what is to come in the absence of aggressive



**FIGURE 12.3** Probability that a given summer across the current cheetah range, during 2070–2099, will be warmer than the warmest on record during the historical period of 1920–2014. The maps depict the much lower probability of unprecedented hot summers if societies adopt aggressive GHG mitigation (B vs. A). Following business as usual emissions [RCP 8.5; panel (A)] will lead to almost every future summer likely being hotter than any we previously have experienced, while with aggressive emissions reduction [RCP 2.6; panel (B)] the probability that future summers will produce record heat is predicted to be much less. Data are the same as used in Fig. 12.2.

GHG mitigation. Unabated emissions (RCP 8.5) will lead to annual mean temperatures 3–6°C higher than preindustrial conditions by the end of this century. Average summer temperatures at that time will exceed the hottest summers ever recorded across most of the cheetah’s current range (Fig. 12.3; Lehner et al., 2016). Even with less certainty about future precipitation, the virtually certain increase in temperature will increase evapotranspiration and put additional stress on water resources. The complications that already have accompanied observed warming will be magnified while competition between animals and people increases.

## Conservation Action

If cheetahs are to survive, stakeholders must engage conservation at local, national, regional, and global levels. Development of integrated livestock and wildlife management plans, like the conservancy model used in Namibia

(Chapter 17) would empower communities to manage local natural resources to benefit directly from wildlife through trophy hunting, ecotourism, and collection of veld products. On a national and regional scale, efforts to save cheetahs and their prey must be embedded in each country’s regional development plans. Adaptation strategies that reduce livestock losses and rangeland degradation, and promote water conservation, will be necessary. On a global scale, efforts to minimize GHG emissions must become every nation’s priority. Natural variations in the climate system impair our ability to exactly predict the local and regional pace and severity of climate change effects. Unabated GHG-forced global warming, however, guarantees that we ultimately will exceed thresholds important to cheetah survival. The ever-increasing human footprint on the landscape, combined with unabated “warming-driven” habitat alteration, likely will spell the demise of cheetahs.

## CONCLUSIONS

We have examined ongoing changes that will profoundly affect the future welfare of cheetahs and the environments of which they are a part. Temperature increases driven by rising GHG concentrations could introduce extreme weather patterns including higher frequencies of drought and in some places more pulsatile rains. The past has shown that cheetahs are directly and indirectly vulnerable to such climate changes. As climate patterns change, a multidisciplinary and adaptive approach, built upon past management successes, will be necessary. Even as world societies work to curb global temperatures, conservation efforts must continue on the ground.

The urgency of action cannot be overstated. Procrastination now will assure catastrophe later. Unlike poaching, overgrazing, or deforestation, the impacts of continuing to pollute our atmosphere with ever-higher concentrations of GHGs will be felt for centuries or even millennia (Matthews and Zickfeld, 2012). If society waits to halt GHG rise, the resulting human nutritional challenges and refugee crises are likely to be greater. The need to address these human needs is virtually certain to shift attention away from conservation of cheetahs and other wildlife. The good news is that most future climate uncertainty is in our hands. We cannot control the natural variation in the climate system but we can control the slope of the rising baseline (Fig. 12.1). At the 2015 Paris Climate Talks in December 2015, nations set a goal of keeping global mean temperature rise below 2°C above preindustrial times (or approximately 1°C above present). The RCP 2.6 scenario approximates the Paris goals, and if world societies can get on that or a similar path, temperatures across the cheetah's range could stabilize at levels much more similar to those experienced in recent history (Figs. 12.2 and 12.3).

The future, therefore, is largely up to us. We can stay on the current path and let our climate continue to change in ways that will negatively

impact the lives of all future generations. We can choose a more gradual slope, or ideally, we can choose a path, like that outlined in Paris, that stops the rise in GHG concentrations, and brings us to a new level baseline. Taking this path could avoid the worst that future global warming has to offer, and engenders hope for the long-term persistence of cheetahs.

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