12 · *African Buffalo and Colonial Cattle: Is 'Systems Change' the Best Future for Farming and Nature in Africa?*

R. A. KOCK*, R. G. BENGIS*, D. FEKADU SHIFERAW, F. GAKUYA, D. MDETELE, H. H. T. PRINS, A. CARON AND M. D. KOCK

Introduction

The African buffalo (*Syncerus caffer*) has historically been maligned in African colonial and post-colonial veterinary and livestock communities because of its reputation for being maintenance hosts for several infectious diseases that can impact the viability of the commercial livestock industry (Michel and Bengis, 2012). We provide here some historical context that justified this position, but will argue that this is an unfortunate and perhaps misguided and out-of-date narrative. The dogma perpetrated throughout colonial times that African livestock systems would naturally follow northern hemisphere production systems and disease control models has been, through retrospective social and economic analysis, challenged: '(…) the assumptions that the high-value/high cost option [in terms of livestock industry] is necessarily the best [in Africa] – and the one that should be striven for – and the low value/low cost [of extensive livestock] is automatically bad news are not upheld' (Scoones et al., 2010). The mandates of veterinary services are almost exclusively set up to protect intensive animal-based agriculture investments and trade. This paradigm is promoted by high-income industrialized countries, and most international trade ignores the impacts on wildlife economic opportunities and the realities of domestic livestock limitations in African countries that face restricted international trade

* Joint first authors.

https://doi.org/10.1017/9781009006828.017 Published online by Cambridge University Press

opportunities. There is also a vested interest in maintaining this situation of perceived risk from disease, especially for the expansion of European breeds and modern intensive systems of livestock agriculture, which are often described as 'improved, productive and efficient' in contrast to African extensive and pastoral systems, reflecting a kind of neo-colonialism.

We argue that as the 'new deal' required by recognition of the Anthropocene becomes accepted, the dogma will change. Future economic, agricultural and overall development models will need to fit into the finite environmental envelop that will constrain human activities by choice or by force. There is a greater appreciation of the negative environmental, climate, health and socioeconomic externalities of intensive livestock systems, and of the need for more inclusive landscapes where biodiversity conservation and local citizens' well-being meet and more value is put on indigenous knowledge and value systems (cf. Gordon et al., 2016). African continental ownership of future policy has been controversial for decades and may well be the final arbiter on this controversy (Artz et al., 1991; Prins, 1989).

The Development of Coexistence of African Pastoralism with Wildlife

Contemporary views on buffalo reach back to the introduction of Eurasian cattle along with the colonization of the African continent. In the following sections, we focus on eastern and southern regions of Africa where most of the 'conflict' is expressed, and mostly exclude western and northern regions of the continent, where cattle herds have deep histories, including truly African breeds (Prins, 2000). Issues between cattle and buffalo in relation to disease are less pronounced in these regions, if only because buffalo are absent in the north and there are only small, scattered buffalo populations in the west where pastoral systems dominate (Kock et al., 2014; Chapter 4).

Before colonization, in the seventeenth century, large areas of the southern and western regions of southern Africa were sparsely populated by the nomadic hunter-gatherer San people and nomadic farmers (Khoikhoi/Khoisan) who were probably the first livestock owners in these southern lands. The more eastern and northern areas of southern Africa were inhabited by primarily Bantu groups who were also pastoralists, owning Sanga (Nguni) cattle, sheep and goats, and also growing edible crops (Maggs, 1986).

The situation in East Africa in the pre-colonial context was composed of extensive grasslands and traditional cattle owning coexisting with abundant wildlife. Wildlife behaviour and traditional livestock practices such as pastoralism and transhumance coevolved in East Africa, sharing space and participating in the engineering of open grassland savannas (Chapter 2). *Bos taurus africanus* or Sanga cattle is generally considered the indigenous African cattle from eastern African origins. African cattle were likely derived from complex introductions over centuries, and even from aurochs in Egyptian times from the Near East (Prins, 2000). Some species from North Africa are recognized to have existed beyond Egypt but are now extinct, for example *Bos primigenius mauretanicus* (Tikhonov, 2008). Along with hybridization between *B. taurus* and *B. indicus* or zebu cattle, a variety of breeds now constitute cattle populations in sub-Saharan Africa. These breeds coexisted with wildlife for over a thousand years and developed some resilience to infection, parasites and drought. Both pastoralism and wildlife may have benefited from each other, co-creating integrated landscapes. Wild ungulates used human-occupied areas to avoid predation by wild carnivores or, in the case of smaller antelopes, to benefit from areas grazed by cattle, feeding off early shoots after heavy cattle grazing (Augustine et al., 2011; Georgiadis et al., 2007; Odadi et al., 2011). In the case of the hirola antelope (*Beatragus hunteri*), the most endangered artiodactyl in Africa today, its survival in a narrow range in Kenya was closely linked to local pastoralists. Hirola, having become extinct elsewhere apart from a small part of Kenya, often concentrate, feeding around nutrient-rich old boma sites and short grasses established by livestock grazing pressure where predators are persecuted. Hence, they benefited inadvertently from traditional pastoralism while indigenous people considered the presence of hirola as a good sign for their cattle (Andanje, 2002). The relationship with wildlife was used to predict resource availability (tracking movements) and as a source of culture and food when necessary (Lankester and Davis, 2016). Presently, with the wide availability of guns, rifles and other weaponry in the hands of pastoralists, this has changed, and the hirola is now next-to-extinct and features on the IUCN Red List.

Archaeological data indicate that diseases at the wildlife/livestock interface may also have been an important component of this interaction. Even with indigenous breeds of cattle, the establishment of pastoralism in some African ecosystems was constrained by wildlife and vector-mediated diseases, such as tick-borne diseases (e.g. East Coast fever, ECF), trypanosomiasis and malignant catarrhal fever (MCF).

Practices such as fire, bush-clearing and contact avoidance, respectively, have taken time to evolve to counter sanitary threats and allow pastoralism to colonize new landscapes (Gifford-Gonzalez, 2000). Most of Africa's livestock farmers practiced (and still do) unfenced extensive systems with indigenous breeds of cattle (historical hybrid *B. indicus* and *B. taurus africanus*). These breeds and systems have proven to be more sustainable and resilient to infectious diseases, parasites, heat and droughts when compared to most *B. taurus* breeds and livestock systems imported from Europe (Mattioli et al., 2000; Morris, 2007). Under conditions of widespread vectors and pathogens in Africa, acquired resistance enables greater sustainability of traditional livestock keeping and resilience in the face of epidemic and endemic diseases. Little control is practiced, and fencing is very limited in its use in African rangeland, mostly to separate a few historical ranches from open range. Most of the separation between buffalo and African cattle herds derives from behavioural determinants, mostly human aggression and use of dogs for reasons other than disease, with an avoidance response from buffalo herds leading to their predominance in protected areas where humans and domestic animals are mostly excluded.

Re-Drawing of the African Landscape – Colonization and De-Colonization – Emergence of Production-Oriented Livestock Systems in Africa

Southern Africa was one of the earliest subregions to be colonized by European settlers, which took place in the seventeenth and eighteenth centuries. The settlers landing in the southern Cape were European with a drive towards settled agriculture and land tenure, which was not part of indigenous tribal cultures. These moves led to major conflicts not only between different European cultures but with several tribes over land and resources. This territorial expansionism by the settlers accelerated in the nineteenth century and culminated in the forming of several nation-states. These included the Boer republics in South Africa and periods of British sovereignty over large areas of southern Africa up to the miombo belts and forests of East and Central Africa, as well as the German colonization of South West Africa (Namibia) and East Africa (Tanganyika, Ruanda-Urundi). In addition, around the end of the nineteenth century, serious colonization of East Africa by the Germans and British happened with Tanganyika ultimately falling under British rule on behalf of the League of Nations.

https://doi.org/10.1017/9781009006828.017 Published online by Cambridge University Press

During these territorial expansion periods, settlers, European hunters, war and disease all eventually had major impacts on wildlife populations. The settlers were heavily reliant on hunting to supply their daily protein needs, and there are many historical accounts of wild herds stretching from 'horizon to horizon' (e.g. Beard, 1977; Prins and De Jong, 2022). There was also a large amount of commercial hunting for dried meat and hides as well as sport hunting for trophies, the slaughter continuing unabated as though the resource was limitless and infinite. These practices were also used to clear land to make space for grazing domestic stock, with wildlife numbers suffering through depredation and competition. In South Africa, the kwagga (*Equus quagga*), Cape lion (*Panthera leo melanochaita*) and bluebuck (*Hippotragus leucophaeus*) were driven to extinction, and the bontebok (*Damaliscus dorcas dorcas*), white rhinoceros (*Ceratotherium simum*) and Cape mountain zebra (*Equus zebra*) were pushed to the brink. Countless animals were killed to feed trading safaris, and colonial armies also were fed meat from game. Lands were cleared of wildlife species to create space for white settlers and local farmers alike, as in Kenya (Adamson, 1968, pp. 97 ff, 120) and many other places. The total number of African elephants (*Loxodonta africana*) killed by elephant control officers in East and southern Africa may perhaps be equal to the number that was poached for their ivory. The onslaught on Kenyan wildlife during World War II is jaw-dropping, where herds of game were used as targets to represent enemy troops and elephant herds were even bombed (Prins and De Jong, 2022).

In southern Africa, the power lay with cattle keeping and agriculture communities during colonization, while National Parks (NPs) were seen as the only way to address perceptions of irrational pastoralism (Lankester and Davis, 2016). Ironically, the strong militarization of protected areas, including the post-independence exclusion of people from traditional lands and even the banning of hunting (both sport and traditional), generated animosity which may even have laid the foundations for the poaching of elephant, rhinoceros and other species after the colonies collapsed. In each of these arenas, there was inevitably conflict. For example, in southern Rhodesia, wildlife were culled extensively to create buffer zones between wildlife-rich areas and colonial farmer production areas for various reasons (Mutwira, 1989), and to target the preferred hosts of tsetse flies in order to reduce tsetse-infested areas and the occurrence of trypanosomiasis (e.g. Zululand; Andersson and Cumming, 2014).

With colonization, pastoralism was also catastrophically reduced through the introduction of contagious bovine pleuropneumonia, followed by the great rinderpest pandemic (the Masai–Maa cultural group was reduced by two-thirds: Prins and De Jong, 2022; Box 12.1). Some wildlife species also suffered huge losses in East and southern Africa, deregulating African savannas' trajectories in the following decades with alteration of the habitat (e.g. bush encroachment; Holdo et al., 2009) and wildlife diversity and abundance (reduction then increase following the space liberated by human populations). The phylogenetic relationship between African buffalo and cattle, although quite distant (Chapter 2), leads to shared pathogens and led to the frequent

Box 12.1 *Impact of the Great African Plague Rinderpest on Livestock Development*

A major event that influenced agricultural thinking was the emergence of novel pathogens exotic to Africa, for example, rinderpest and contagious bovine pleuropneumonia or CBPP (Chapter 9). The great pandemic of the late nineteenth century caused by Rinderpest (a morbillivirus) killed almost all cattle it infected and wiped out a large proportion of the indigenous wildlife herds from North to South Africa, resulting in huge epidemics in buffalo with massive mortality. In many cases, only small relict populations of some species survived in remote pockets or were entirely extirpated from their former ranges. Impacts were seen on some keystone species including migrating East African wildebeest (*Connochaetes taurinus*). This had major impacts on the scale of migration and habitat with a transformation in vegetation types and distribution (Holdo et al., 2009).

Veterinary services were launched at about the same time as colonial administration became established, with the task of disease control to support the further development of livestock systems. Ironically, the loss of indigenous breeds made way for the colonists to import European breeds and hybrids favoured for their high potential for milk and meat production. These colonial cattle herds, with their innate vulnerabilities, soon came into conflict with buffalo in southern Africa.

These changes were reversed, with the elimination of the virus (officially in 2011) proving a strong disease and ecology relationship, uncommonly proven.

accusations of the buffalo being a reservoir of key livestock diseases during colonial and post-colonial eras. The buffalo became synonymous with the early concept of the so-called wildlife–livestock interface in Africa (Kock, 2006), showing the buffalo's prominent role in several diseases (Chapter 9). During colonial times, the epidemiology was poorly understood and quantified, and most of the evidence was derived from a few human-altered ecosystems, mainly in southern Africa. At least in this region, the negative perception of wildlife and diseases led to clear segregation of land uses dedicated to livestock production and the separation of domestic and wild ecosystems. New diseases and pressure from white colonialists forced traditional pastoralists and their livestock into newly emerging tsetse fly (*Glossina* spp.) belts (Prins and De Jong, 2022). In East Africa, this was less of an issue because local livestock and forestry, for instance, could be combined (Brasnett et al., 1948). This divergence between concepts of 'modern' livestock agriculture and traditional pastoralism, between the south and the north, took on sociocultural and political dimensions. During colonial or European rule, a narrative against traditional local livestock keeping in Africa developed, and this has persisted to some extent, frequently justified by the disease paradigm and from where the power in control policies lies, which is mostly within industrialized western nations. This was understandable given that epidemic and vector-borne livestock diseases were a major constraint to the expansion of European livestock systems in southern Africa (e.g. Gunn, 1932), while in the east and west of the continent, the pastoral systems thrived. Attempts at ranching cattle gradually declined over the twentieth century in East Africa, with large landholdings reverting successfully to wildlife–cattle integrated management with meat and tourism activities and, sometimes, communal ownership (NRT, 2020).

Positively, the colonial era inspired protection of game and areas of land in law. However, as royalty had given hunting rights exclusively to the wealthy in Europe, colonialists discriminated against local people and limited people of pastoral communities' access, making wildlife a preserve of the rich behind a conservation banner. People and animals were negotiated or shifted away and excluded from extensive productive rangelands, and this has persisted to this day.

The pattern of wildlife decline was repeated in eastern and Central Africa during the period of decolonization from the mid-twentieth century. Indigenous communities and rebel armies slaughtered game in the transition periods, partly during conflict for food, and to push back against colonial masters, conducting revenge killings after years of exclusion and to avoid future restrictions by eliminating game. However, some positive post-colonial developments based on the colonial systems should be noted. For example, in Kenya, these included much-debated bans on hunting (Anon., 1977) in attempts to slow the decline in wildlife; improved protection agencies; and eradication of rinderpest, a big killer of buffalo (Kock, 2006). These measures appear to have stabilized buffalo numbers, at least in Kenya, over the last three decades (Grunblatt et al., 1996; KWS, 2021). Ironically, after the end of the colonial era, the same colonial model of disease management was adopted by emerging states with identical results. For the natural ecologies in these areas to recover, old paradigms had to be overturned or remain to be challenged. Interestingly, in the fields of human health and global health, this theme has also been gathering momentum as shackles remain on poor countries and a few high-income countries dictate the human health and health industry agenda (Büyüm et al., 2020).

Current Situation at The Interface, The Burden of History and the Weight of Changes

Today, many new pressures, including climate change, human population growth, associated buffalo–cattle–human conflicts (Matseketsa et al., 2019) and agriculture (Prins and De Jong, 2022) are reducing the viability of buffalo populations, now highly dependent on protection. In much of sub-Saharan Africa, with under-investment from abroad, land-use pressure is mounting with heavy investment in extractive industries, including forestry, and mining, while the human population is growing at a particularly high rate. This human population impact on land is, to some extent, compensated by urbanization, but demand for food continues to grow. As a result, the lands that were designated for wildlife and pastoralism are being encroached on and put under increasing pressure. Increasing populations of livestock, more or less replacing wild ungulates, have been documented in some countries and regions such as Ethiopia (Gebretsadik, 2016), and countries with strong wildlife economies like Kenya have also been affected, but at a slower rate (Ogutu et al., 2016). Political power lies in the hands of urban communities and agriculturalists, while pastoralists are weakly represented in government. These communities have historically been persecuted and discriminated against through land-use policy that removes key resource areas from their control. Some of these conflicts, especially in West and Central Africa, remain serious and violent, with recent examples within the Fulani (a.k.a. Peul) pastoralists community around the Lake Chad basin. Today, there is an East and Central African model, where open rangeland remains available and true pastoralism and transhumance are still practiced, and a southern African model, where land tenure has dominated the scene for the past 200 years, and little 'open' rangeland still exists.

The 'trade sensitivity' around the main diseases impacting livestock production that were prominent in Europe at the time of colonization was simply transplanted into African colonial systems (see, for instance, Empire Marketing Board, 1930). In some regions of sub-Saharan Africa, disease in wildlife is still seen by animal health agencies as a significant barrier to agricultural development. However, we posit, that is mostly a result of residual dogma and supporting narrow policies that benefit the main agribusinesses trading in a globalized world. Veterinary fencing, with a primary role to separate buffalo from cattle populations, has been used extensively across southern Africa (Chigwenhese et al., 2016; Ferguson and Hanks, 2010), but is cropping up in Europe too (like the wild boar fence separating Denmark from Germany) and has been in place in Australia since the end of the 1800s. Even until the present day, the government veterinary services of South Africa, Zimbabwe, Botswana and Namibia all practice so-called 'hard edge' disease control measures, which include barrier fences such as the Kruger NP (KNP) western and southern boundary fence (restricting contact with livestock in South Africa – while the eastern Mozambique fence is only partially closed), the Ngamiland buffalo fence (partly separating the Okavango Delta from livestock areas in Botswana) and the Namibian veterinary cordon fence to prevent contact between commercial livestock and wildlife, particularly buffalo. In Zimbabwe, 55 per cent of the buffalo population is fenced today, and this policy is sometimes supported by conservation non-governmental organizations (NGOs) sharing an interest in preventing cattle and people from entering the protected areas and wildlife from getting out. A similar cordon line exists between Western Zambia and Angola. These veterinary measures clearly separate commercial livestock production that is protected for their markets versus wildlife systems and small-scale livestock production imprisoned in the fenced areas and unable to be marketed. Indeed, Botswana's fences protect blocks that are designated for commercial trade with a foreign region (European Union) and certainly constrain local production and compromise local food security, with devastating consequences on wildlife communities and ecosystems. To show the tenacity of such beliefs and practices, the Veterinary Cordon Fence in Namibia was enacted by the German Reichstag in 1905, and still discriminates between livestock producers from beyond the fence and those 'on the right side' of it (e.g. Miescher, 2012; Tjaronda, 2008). In addition, certain designated geographical control zones have been declared for diseases such as foot and mouth disease (FMD), African swine fever and corridor disease (buffalo-associated theileriosis) in South Africa. As in Botswana, these are primarily intended to protect designated production zones exporting to high-end meat markets. Its mirror side, however, is that by framing cattle meat as coming from potentially 'dangerous' areas where veterinary control may be wanting, farmers in these importing countries are enabled to prevent competing meat from coming to 'their' market (Robinson, 2017; Whittington et al., 2019). This fencing policy, mostly imposed by the state on local stakeholders is costly, opposed by pastoralists and accepted by commercial livestock and crop farmers for obvious reasons. In all but a few cases (UNEP, 2011), fences are detrimental to wildlife movements and conservation, and they require significant maintenance (De Jong et al., 2020; Gadd, 2012). In the absence of good maintenance, fencing deteriorates and becomes porous (Chigwenhese et al., 2016).

However, to some extent fencing for disease control and for reducing wildlife conflict with people and agriculture has taken hold in much of the continent. In East Africa, arguments against this approach seem to have helped to slow any progression down this path for reasons of disease control (Kock, 2010). In many situations, with open interfaces between protected areas and communal land, buffalo's natural and adaptive avoidance of cattle reduces the risk of disease spillover, and these systems show high tolerance to infection without many diseases expressed (Caron et al., 2016; Meunier et al., 2017; Valls-Fox et al., 2018). In times of drought, contact rates can change dramatically and disease epidemics are more likely to occur (Bengis et al., 2002; Kock, 2005). A severe drought in Kenya from 1993 to 1994 probably precipitated the large rinderpest outbreak in the 1990s in East Africa (Kock et al., 1999, 2006), killing 60 per cent of buffalo in the Tsavo National Park ecosystem. However, this drought killed some 70 per cent of the buffalo in the Masai Mara even before the disease arrived (Dublin and Ogutu, 2015). In East Africa, livestock remained in open pastoral systems and coexisted with wildlife, which thrived (Homewood et al., 2012), but mostly with buffalo only surviving in protected areas and buffer zones. Agropastoral, farm or ranching communities and pastoralists are known to use self-managed movement control to avoid epidemics. However, increasing densities of people and their livestock ultimately can continue to lead, in the absence of new policy, to the demise of wildlife (Prins, 1992; Prins and de Jong, 2022). This is not inevitable; for example, more integrated developments in pastoral land use, such as in Kenya, have led to remarkable overall stability in wildlife populations over decades, despite rapid development, human population expansion and declines of wildlife on state lands (KWS, 2021).

When there is insistence on disease elimination rather than control in livestock, the interface becomes more threatening. De Vos et al. (2016) clearly described, for example, the challenge in South Africa of perceptions around certain species and diseases stating,

> The majority of endemic pathogens found in protected areas do not kill large numbers of wild animals or infect many people, and may even play valuable ecological roles; but occasional disease outbreaks and mortalities can have a large impact on public perceptions and disease management, potentially making protected areas unviable in one or more of their stated aims. Neighbouring landowners also have a significant impact on park management decisions. The indirect effects triggered by disease in the human social and economic components of protected areas and surrounding landscapes may ultimately have a greater influence on protected area resilience than the direct ecological perturbations caused by disease.

In more extensive pastoral systems, wildlife and livestock remain integrated to some degree, with designated protected areas allowing the survival of core buffalo populations. The protected area models adopted in West and Central Africa, with core protected areas surrounded by buffer zones with limited human activities (e.g. game hunting, some pastoral activities) offered management of the buffalo/cattle interface that has allowed the survival of core buffalo populations, even if isolated (Bauer et al., 2020), as long as there was no security crisis. That system has subsequently collapsed in many places in West and Central Africa (Scholte et al., 2021), and perhaps only timber concessions and privately managed reserves appear to maintain buffalo (Chapter 4). Even though open systems have allowed wildlife to thrive, buffalo are not tolerated by pastoral livestock owners due to the aggression sometimes shown by buffalo to pastoralists and direct competition for water and grazing. This has led to the virtual extirpation of buffalo from some communal lands (Metzger et al., 2010). There are a few exceptions with forest buffalo (*Syncerus caffer nanus*) and some savanna buffalo in forested areas such as Boni Dodori in Kenya, where large populations >10,000 share habitat with hunter-gatherer/small-scale cropping communities (Chapter 4). A similar peaceful coexistence can be seen in along the Kazinga Channel between Lakes Edward and George in Uganda (Kock, personal observation).

Where a wildlife economy dominates as a source of foreign exchange revenue over agriculture, such as in Kenya and Tanzania, the political establishment lends a more sympathetic ear. In addition, and perhaps as a result, all attempts at draconian veterinary measures detrimental to the wildlife and pastoral economy have never been applied successfully, even if policies exist on paper. A sustainable balance is often achieved, allowing for livestock keeping and healthy wildlife populations to be conserved and contributing to tourism and the economy. Increasingly this tourism industry is locally owned and beneficial to indigenous communities (Mureithi et al., 2019; Tyrrell et al., 2017; Western et al., 2020). While in the south of the continent, where livestock owners were well connected politically and largely dominated the land-use arguments in favour of agriculture for over a century (Munangándu et al., 2006), this has been reversed to some extent more recently, with an expansion of wildlife ranching and conservancies (Chapter 13). In many of these ranches and conservancies in South Africa, integrated farming with livestock and wildlife now takes place, but with the exclusion of buffalo and large predators. Legislation dictates that buffalo and cattle may not be kept on the same property.

In addition to these influences, a failure to invest in local communities around wildlife protected areas brings more pressure. Estimates of locally shared revenue from conservation areas like the Serengeti are only 5 per cent of total annual income and only go to a few households, with the majority of beneficiaries being a distant private sector and government exchequers (Homewood et al., 2012; Lankester and Davis, 2016). In Zimbabwe, where *Operation CAMPFIRE* first resulted in much higher revenue sharing with local communities, this community benefit fell to only a few euros per year after the CAMPFIRE strategy was 'invaded' by local politicians and bureaucrats (Poshiwa et al., 2013a, 2013b). We are not judging what was or is right or wrong in this debate on 'human versus biodiversity rights', but are trying to present the different perspectives and historical precedence around disease which may explain past and current actions.

Recovery of African Pastoralism and Wildlife in Africa – Is This Possible?

With ongoing climate change and continuing human population growth, as resources decline and drylands increase, the use of available water from rivers and wetlands will probably increase the likelihood of buffalo and cattle meeting. Increased grazing pressure may result in ecological disturbance and degradation of natural resources. If this progresses, the natural disease regulation benefits of the ecosystems may begin to decline and vector–host–pathogen dynamics may be disturbed, which will impact livestock more. Eventually, wildlife may also suffer as malnutrition and stress erode even their resilience to disease, and whole ecosystems may begin to decline with population crashes. As buffalo are removed from pastoral or agriculturally designated lands, they are still frequently blamed as a source of diseases for livestock kept by communities surrounding the conserved areas where buffalo are mostly found. In addition, the ecological consequences of agriculture, ranching and overall degradation of fenced land, especially with high stocking rates, create poor conditions for ungulates and increased vulnerabilities to disease irrespective of the presence of carrier animals peripherally or in the parks (Glover et al., 2020; Kinne et al., 2010). However, the conflict remains high in livestock keepers' minds. As populations of cattle grow, the domestic animals themselves become more epidemiologically significant, through a mere numerical relationship, and become the main carriers of diseases and a preferred food source for disease vectors (Channumsin et al., 2019; Clausen et al., 1998). This can change the epidemiological dynamics of pathogens locally, shifting the role of wild and domestic species, and can drive the further spread of disease within the domestic population, the community of wild and domestic ungulates, which may include spillback to wildlife.

With today's improved epidemiological knowledge, better diagnostic tests and better livestock vaccines, it is hoped that African endemic disease control can become less conflictual and more environmentally friendly. The movement of diseases between wildlife and livestock is in fact bi-directional. With dwindling wildlife numbers in many countries (especially in West and Central Africa: Chapter 4), wild animals can also be threatened by persistent livestock disease spillover (e.g. bovine tuberculosis, peste des petits ruminants and brucellosis) to naive and sometimes critically endangered wildlife (Pruvot et al., 2020; Shury et al., 2015; Viggers et al., 1993; White et al., 2011; Chapter 9).

More recently, changing views on livestock management and values of wildlife have resulted in the fading away of earlier red lines

https://doi.org/10.1017/9781009006828.017 Published online by Cambridge University Press

on diseases such as FMD (Ferguson et al., 2013; Weaver et al., 2013). Strengthening wildlife-based economies in Africa, and innovative thinking around integrative management of wildlife and livestock and the rangelands in which they coexist, are increasing environmentally friendly land uses (Ferguson et al., 2013). Development of softer disease policies such as the use of commodity-based trade (CBT) to circumvent FMD trade restrictions renders FMD elimination an obsolete goal (Thomson et al., 2013) even if currently its acceptance remains slow. Nevertheless, there are now increasing opportunities for trade without disease control burdens. The emphasis on intensive husbandry of livestock with production and profit as the main goal is shifting towards more sustainability in food systems. Other benefits of mixed rangeland management include climate change mitigation and reduction in disease control costs. Perhaps the ultimate arbiter of future livestock systems will be the concerns over their role in biodiversity loss, as competitors for food crops which might otherwise be used for humans and climate change ramifications. A shift from animal- to plant-based diets is gaining momentum in many countries in Africa where meat consumption remains low per capita compared to other continents while biodiversity remains high (Figure 12.1).

In South Africa, a buffalo production model emerged in the 1990s and has evolved to this today with controversial outcomes (Box 12.2). The more visionary wildlife ranching and community-based natural resource management (CBNRM) practiced in Namibia and Zimbabwe since the 1970s, utilizing mainly the extensive and relatively free-range systems and conservancies, has been important in bringing communities on board. Kenya and Tanzania have taken strides in recent decades, with integrated pastoral livestock and wildlife ecosystems such as the Northern Rangeland Trust and Ngorongoro Conservation Area, respectively. However, upheavals and violence in the latter area in 2022 may throw another light on the success of this narrative (Kihwele et al., 2021; ROAPE, 2022). In regard to such initiatives, South Africa is lagging behind, with Uganda and Ethiopia and countries in West Africa (with large and small buffalo populations) even more so.

Under several proposed future alternative development scenarios, if land is released from animal production for rewilding, disease epidemics are likely to decrease without abundant domestic animal host populations. Historic concerns about wildlife as disease reservoirs will dissipate, resource competition will decline and wildlife-based economic opportunities will arise.

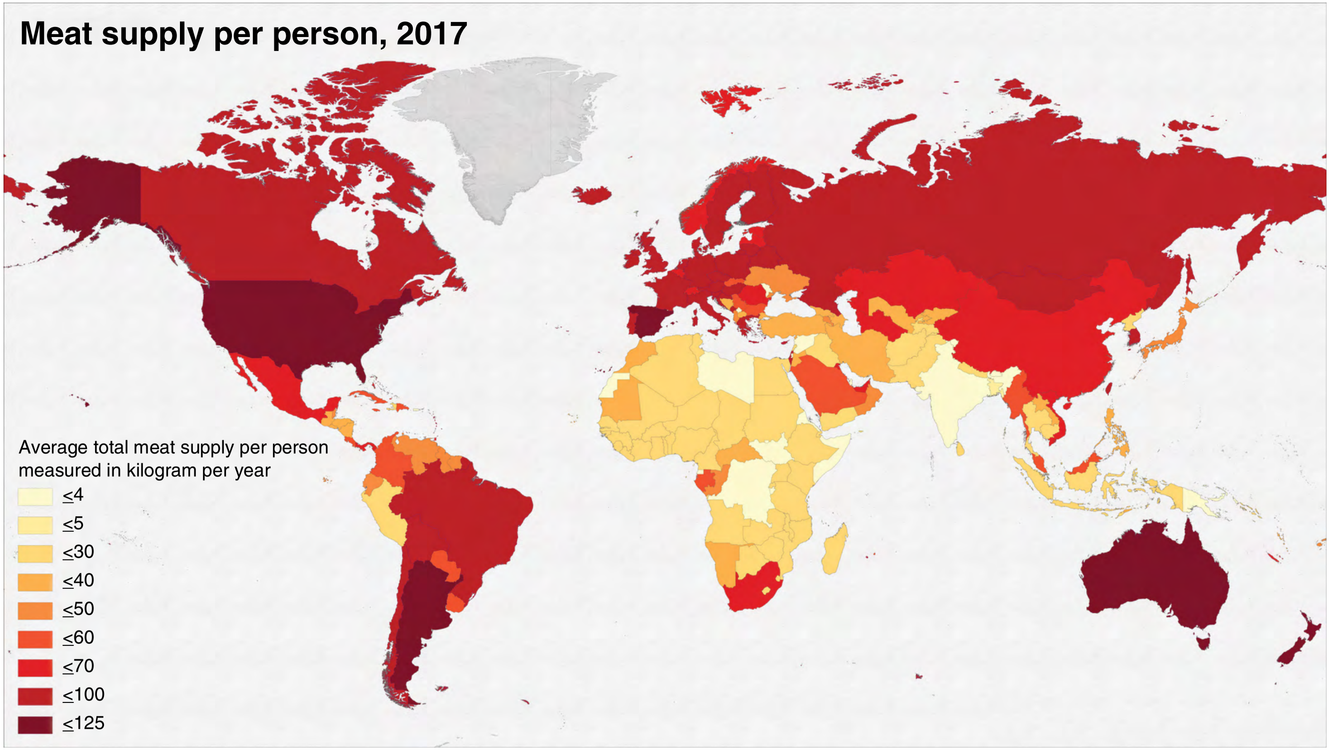

Figure 12.1 Meat supply per person in 2017 (Source: FAO, see interactive map at https://ourworldindata.org/meat-production). This illustrates how the narratives around Africa and meat consumption are largely distorted. Africa has much more sustainable low-impact animal-based agriculture and wild meat consumption in terms of environment, biodiversity and climate change. A wildlife economy continuing and developing alongside an agricultural economy in Africa could address and prevent many of the challenges currently facing advanced economies.

https://doi.org/10.1017/9781009006828.017 Published online by Cambridge University Press

Box 12.2 *Buffalo as a Production Animal in South Africa: A Case Study*

The uses of buffalo as a production animal or for trophy hunting are covered in Chapters 13 and 16. However, it is pertinent to showcase the intensification of buffalo production (semi-intensive and intensive production systems: Chapter 13), separated from cattle production but along the modern northern hemisphere economic model (privatization, compartmentalization, commodification of nature for capitalist markets) within a sector sometimes disconnected from nature.

In South Africa, KNP authorities developed a project between 1996 and 2006 in response to concerns about invasive bovine tuberculosis (bTB) and the unique genetics of their infected buffalo population, as well as commercial interests (Bengis and Grobler, 2000). The objective was to breed specific pathogen-free (SPF) buffalo calves from infected parent stock. Approximately 460 SPF buffalo calves free of FMD, theileriosis, bTB and bovine brucellosis were produced during the lifetime of the Kruger project. Many more so-called SPF calves were also produced from infected parent stock in private facilities within the FMD control zone. The offspring of these original buffalo were translocated to other NPs that did not have buffalo, which was in itself a major conservation goal, and today, Pilanesberg, Vaalbos, Marikele, Mountain Zebra and Mokala NPs all have viable, relatively free-ranging populations of Kruger buffalo in multi-species and extensive systems. Some SPF offspring were also supplied to private wildlife ranches throughout South Africa. Today, these privately owned SPF buffalo are being kept under intensive, semi-intensive and extensive conditions. Under more 'controlled' and intensive ranching conditions, population health appears to deteriorate and any resilience benefit of wildlife over cattle is diminished. Diseases in intensively managed captive buffalo further show this tendency for a shift in pathogenicity when animals are removed from their natural ecosystems with, for example, FMD expressed through weight loss and lymphadenopathy (Vosloo et al., 2007), bTB and Rift Valley fever-associated morbidity and mortality also expressed under certain conditions (Beechler et al., 2015). With these more intensive systems, endo- and ectoparasite control also became important. In addition, some SPF buffalo raised under conditions of minimal exposure to disease vectors have actually died from theileriosis, MCF and even heartwater after significant tick exposure or contact with

https://doi.org/10.1017/9781009006828.017 Published online by Cambridge University Press

wildebeest or sheep. These are diseases to which buffalo are normally totally resistant.

The fact that these SPF buffalo are now present on wildlife ranches in all nine provinces of South Africa has been problematic for the State Veterinary Services. Legislation requires that all farms that have buffalo must be registered, and any buffalo movement from one property to another requires animals to be retested for all four diseases. There is also concern over veterinary management options should an outbreak of any of these dreaded diseases occur in this diffuse privately owned population. This concern has continued to lead to discrimination against buffalo in the last decades; for example, SPF buffalo breeding project expansion in South Africa has been curtailed by the Veterinary Department. As the evidence shows, replacing a commercial domestic cattle model with a wildlife ranch model may not work as any intensification and interruption of natural ecological processes is fraught with problems and disease is clearly one.

Some of these trends relate to the veterinary controls and historical separation of animals and subsequent commercialization of wildlife species. In this regard, the difference between extensive versus more intensive forms of buffalo production needs to be appreciated. While extensive systems can certainly achieve important conservation goals, in contrast, the more intensive forms of production, despite claiming to be contributing to species conservation, are not recognized by conservation bodies such as IUCN. The recent legal change in South Africa where some of these species may be listed as farming animals for intensive commercialization further demonstrates this shift and effectively disconnects these populations from nature. Animals raised in these intensive production systems should not be used for conservation purposes, such as reintroductions or reinforcements of natural populations, due to the risk of introduction of production diseases or of animals which are 'disease-free' becoming exposed to natural disease cycles. In addition, a potential genetic shift and/or altered production genes may be deleterious to natural ecologies (cf. wild boar *Sus scrofa*; Martínez-Avilés et al., 2020). Land uses in which SPF buffalo are produced intensively and artificially selected should not be connected to natural ecosystems or protected areas for conservation purposes.

Are Buffalo and the Diseases They Carry Still a Concern in the Modern African Landscape?

As observed, the diseases which have been much thought of in the context of buffalo and cattle are African strains of FMD, corridor disease (theileriosis), bTB, brucellosis, trypanosomiasis, heartwater and Rift Valley fever (Michel and Bengis, 2012; Chapter 9). African buffalo are believed to serve as maintenance or incidental hosts and amplifiers of these cattle diseases with potential spillback (Musoke et al., 2015). However, there is relatively little supportive evidence for spillback happening, and new evidence is challenging long-held assumptions. In truth, cross-species infections are rarely documented or confirmed, but epidemics can occur, especially where there is a policy on disease elimination in livestock, and a hard boundary between disease-free and infected populations created by fencing. The following paragraphs provide examples to illustrate the trends.

There is no doubt that FMD SAT strains are maintained by buffalo, and they may represent the original coevolved host (Anderson et al., 1979; Thomson and Bastos, 2004). However, as with many 'emerging' infectious diseases, confirming origins retrospectively is nearly impossible. Cattle that are FMD-free can be at risk of a breakdown in status at any interface with buffalo and other carriers of the virus (Guerrini et al., 2019; Hargreaves et al., 2004; Miguel et al., 2013). However, even this strong narrative of buffalo being the original sole 'source' of SAT strains of FMD in Africa is now in question. Buffalo may perhaps have been so historically, but more recent evidence in certain regions of the continent shows that cattle can also maintain cattle-adapted SAT strains for extended periods (Omondi et al., 2020; Wekesa et al., 2015). Not all cattle outbreaks with SAT viruses might have been from buffalo, but in several southern African countries, cattle outbreaks have been shown to be caused mainly by buffalo isolates. Many of these buffalo isolates that are regularly mutating have subsequently been incorporated into cattle vaccines.

Some vector-borne diseases – for example, the tick-borne disease theileriosis and heartwater – can cause very high mortality (up to 100 per cent) in naive African cattle (Lawrence, 1992; Neitz et al., 1955), while certain exposed cattle populations living at extensive buffalo/cattle interfaces suffer fewer losses (Young, 1981). As with FMD, cattle-adapted *Theileria* strains have evolved and emerged, causing the diseases known as East Coast fever (ECF) and Zimbabwe theileriosis (January disease),

https://doi.org/10.1017/9781009006828.017 Published online by Cambridge University Press

and these diseases can circulate independently in cattle without any buffalo presence. In addition, with regards to heartwater, the development of premunity and endemic stability has resulted in fewer losses. Other vector-borne diseases can have multiple reservoir hosts. With trypanosomiasis, wildlife certainly provides reservoir hosts, some preferred by tsetse flies, such as buffalo, wild porcines, spiral-horned antelopes and elephants, but from a risk perspective, these populations can also dampen environmental infection loads away from livestock and humans, reducing disease risk and impacts (Channumsin et al., 2019; Clausen et al., 1998). As with the Rift Valley fever virus, buffalo are susceptible but are only one among a myriad of susceptible wild and domesticated ruminants (Swanepoel, 1976).

On the bacterial side, even if livestock-origin brucellosis and bTB have crossed the 'species barrier' many times, their impact on free-ranging populations of buffalo appears to be ecologically insignificant. For brucellosis, this is true even in populations where brucella spp. antibody prevalence is quite high, as in KNP, South Africa (De Vos and van Niekerk, 1969; Herr and Marshall, 1981; Ndengu et al., 2017) with occasional reports of disease in buffalo and spillover to other species (Condy and Vickers, 1972; Gradwell et al., 1977). Certainly, the observation of hygromas in older buffalo is not uncommon throughout the buffalo range. Much more has been published on bTB in buffalo, but almost exclusively focused on South Africa (but see Sintayehu et al., 2017a), where it is thought to have been introduced with cattle imports in the eighteenth and nineteenth centuries (Paine and Martinaglia, 1928). The most attention is given to the 'compressed' fenced or semi-fenced protected areas such as KNP and Hluluwe/Umfolozi NP (Bengis et al., 1996; de Garine-Wichatitsky et al., 2010), with high buffalo densities. Here, there are concerning trends with buffalo apparently suffering some disease and mortality. There is evidence that this species is also driving infection in other wildlife species such as lions, *Panthera leo* (Keet et al., 1996), greater kudu, *Tragelaphus strepsiceros* (Keet et al., 2001) and chacma baboons, *Papio ursinus* (Keet et al., 2000). This has raised conservation concerns regarding less-populous species and predator/scavenger impacts. In more open unfenced systems in Uganda, bTB was confirmed around the 1960s and seroprevalence for bTB has been consistently high in buffalo over the intervening years, yet the disease is rarely reported (Guilbride et al., 1963; Meunier et al., 2017; Woodford, 1982a, 1982b). In Ethiopian pastoral systems, and likely in other pastoral systems too, the patterns of bTB are closely linked to human social networks (Sintayehu et al., 2017a). There are also efforts in Ethiopia to establish risk factors for cattle TB associated with wildlife (Sintayehu et al., 2017b). These are multi-species and slowly developing diseases with a long time course before clinical expression, and they are both zoonoses, so need to be monitored.

Anthrax is another multi-species disease that occurs on most continents, and in Africa epidemics occur in wildlife and these are sometimes associated with epidemics in livestock (Mukarati et al., 2020). Epidemiologically, this spillover may well be mostly driven by insect mechanical vectors such as blowflies and biting flies and through contamination of browse, pasture or water (Bengis, 2012; De Vos and Turnbull, 2004; Ebedes, 1976; Hugh-Jones and De Vos, 2002; Prins and Weyerhauser, 1987). Evidence from Ethiopia suggests some significant recorded events in wildlife occurred after a series of livestock outbreaks (Shiferaw et al., 2002), and in the Serengeti, wildlife anthrax epidemics tend to occur during droughts, clustered around contaminated sites such as water holes/salt licks and similar locations where aggregation and mixing of species can occur (Hampson et al., 2011).

It certainly can be argued that introduced cattle diseases on the African continent have had impacts on both the cattle industry and wildlife. Indirectly, the impact on wildlife has been seen through the implementation of control measures. Fortunately, in open mixed rangelands systems, these introduced diseases and the buffalo-endemic diseases are of little consequence to wildlife populations, other than rinderpest. There is a need to re-evaluate historic and modern disease dialogues, rather than perpetuating the old narratives and the prejudice against wildlife as disease reservoirs.

Buffalo have attracted significant research, often becoming the centre of investigations, with this focus perhaps reinforcing preconceptions of their relative disease role and significance. Of 79 publications recorded in a scoping review on viruses in ungulates (Swanepoel et al., 2021), 41 were on FMD in buffalo. This high number is most probably due to the funding available and international interest among researchers for this disease. Buffalo are overstudied without considering other species found in the same environment or the role of cattle themselves in the persistence and spread of infection. As a consequence, the roles of these other wild ungulates (e.g. greater kudu, Thompson's gazelle [*Gazella thomsonii*], impala [*Aepyceros melampus*] or blue wildebeest [*Connochaetes taurinus*]) are relatively unknown despite evidence of their role in a few specific breakdowns and cattle epidemics historically (Weaver et al., 2013). In KNP, which has an endemically infected buffalo population, clinical spill-over FMD has also been confirmed in impala, greater kudu, bushbuck (*Tragelaphus scriptus*), common warthog (*Phacochoerus africanus*) and giraffe (*Giraffa cameleopardalis*), but with relatively mild symptoms observed rarely (e.g. impala; Vosloo et al., 2009).

Towards a New Vision

In the context of disease transfer between buffalo and cattle, who is to blame? The most significant problems for wildlife and cattle stem from the introduction of exotic breeds and their diseases into Africa and the production and trade model that came with them. Models of coexistence between buffalo and African cattle breeds existed during the pre-colonial era only to be disturbed by the introduction of susceptible European breeds and their northern hemisphere pathogens during the colonial period. In addition, the endemic disease risks to introduced cattle, especially for the so-called improved breeds, are very high. The full benefits of buffalo (as a comparable bovid) in the context of the animal and land use are clear but are not being realized, except in some specific land use examples. Most buffalo populations have been reduced to small relict herds, especially in West and Central Africa. If buffalo go extinct, cattle will provide poor compensation for this highly adapted species.

On the other hand, from a disease risk perspective, the management of wildlife species such as buffalo along similar lines to livestock production makes little sense. Extensive free-ranging unfenced systems are already of proven value for harvesting, sport hunting and tourism, and as bulk grazers in maintaining ecosystem's integrity and function. The history of the development of both cattle and wildlife managed systems in Africa and trends in associated disease problems provide abundant evidence for this conclusion. The resilience and health of species are highly connected to the ecological resilience of the systems in which they have coevolved. Therefore, it is likely that community-based (pastoral) systems that can be mixed, rather than agribusiness-driven fenced monoculture (wild or domestic), are a route to sustainable tourism and animal-based food production systems and economies in Africa. Much of African livestock and wildlife will remain more or less in open conditions for the foreseeable future, and thus these systems should be reinforced by appropriate policy and investment rather than discriminated against. This approach has the added value of ecological recovery of highly degraded landscapes from over-intensive livestock agriculture, reinforcing biodiversity conservation, supporting the delivery of natural ecosystem goods and services as well as related income streams. It could innovatively contribute to the target of 30 per cent of land protected by 2030 recently set by the High Ambition Coalition adopted by 69 countries (HAC, 2021). The ambition is high indeed, but realities on the ground suggest it will simply be too late in many countries to progress before major land-use changes and settlements have degraded habitats, especially in Central African savannas (Scholte et al., 2021). Climate change mitigation benefits will also accrue, while still contributing high-quality protein and food security, in a continent that has the lowest meat consumption per capita on Earth. However, to achieve this means shedding colonial legacies around land use and tenure, livestock development and animal health production systems imposed on Africa. It may require reversion to more traditional views on extensive animal use, harvesting and integrated low-cost–low-risk systems of management that are not new and were widely discussed in the twentieth century (Asibey,1974; Dasmann, 1964; Ledger, 1964).

As a new community of scientists and veterinarians emerges across Africa with a novel vision, knowledge from the past and ideas about future agro-ecologies and mixed land use will likely come into play. What may help is that there is now a major shift in perception of animal-based food systems in the very countries that promoted intensive livestock production in Africa. The question that really matters is what do Africans think of alternate futures? Will they remain embedded in old development dogma, or will they surf on the economic and cultural opportunities offered by wildlife? Could mixed land use become a dominant policy? Already, new land management, with mixed livestock and conservation initiatives, has shown considerable success in Namibia and Kenya, building on earlier innovation in Zimbabwe under the CAMPFIRE project, which under difficult political and economic circumstances remains nascent.

New ideas and opportunities beyond conventional systems of agriculture and wildlife protected areas will undoubtedly emerge, becoming hopefully more conducive to both local economic growth, ecosystem stability, resilience and biodiversity conservation. Planetary health demands it. In this chapter, we have shown the need for a reappraisal of history and the risk in the context of buffalo and diseases of concern to the livestock industry. Much of the narrative for 'land clearing' of wildlife is historic and 'blames' buffalo for diseases such as FMD, tick-borne infections, brucellosis and bTB, which early on justified fencing and the compartmentalization of land. In many cases their roles in the epidemiology of these pathogens are tangential and no longer highly significant in evolving contexts in which cattle populations are exploding and buffalo populations are maintained or decreasing in many ecosystems.

The genetic modification of farmed animals for objectives of higher production creates breeds more susceptible to pathogens when buffalo are disease-resistant in African contexts. Putting them together does not make the buffalo the culprit. The current industrial approach may work in highly transformed temperate systems but not in Africa's landscapes, where there is high microbial and vector diversity and a multitude of hosts. This failure of livestock intensification to develop in Africa without subsidization has led to the narrative that it is only through promoting greater separation and higher biosecurity that animal-based food economies can develop and reduce the risk of catastrophic disease epidemics in heavily invested livestock industries. This is basically underpinning policy on disease control and has been supported by unrealistic standards in disease management generated by the World Animal Health Organization (WOAH). These industries are effectively highly subsidized through international funding, and agencies are dedicated to forcing through these agricultural development agendas. Ironically, most of the benefits from these policies accrue to high-income countries that are not African, for instance through blocking access to their lucrative markets. Globally, these policies have come at a major cost to biodiversity and ecosystems in return for little more than cheap protein and high profits for agribusinesses. Africa now stands to gain substantially from shifts in diet, with reduced meat consumption and an increasing acknowledgement of the value of natural land and biodiversity. None of the externalities from, for example, climate change impacts to the loss of habitats or biodiversity are currently born by the livestock industry, although the internalization of these externalities has been called for by the Ecosystem Approach (Principle 4) under the Convention of Biological Diversity (CBD Decision COP V/6) and again under the Principles for Sustainable Use by the same (binding) Convention (CBD Decision COP VII/12). This situation will change as there is increasing pressure for accountability and determination of externalities of various industries for future sustainable development. Buffalo may well still have a bright future.

Acknowledgements

The co-authors would like to dedicate this chapter to Dr Gavin Thomson, who died in April 2021 just before finalizing this text. His passing is a great loss to the veterinary and wildlife health communities. He was an African who had a long research history working on FMD, including as one-time Chair of the FMD Commission of the OIE. He was a convert to supporting contemporary views on buffalo and the reappraisal of FMD control policies for Africa, inspiring commodity-based trade in his later years. Gavin was in the end a true conservationist.

References

Adamson, G. (1968). *Bwana Game: The Life Story of George Adamson*. Collins: London.

Andanje, S.A. (2002). *Factors Limiting the Abundance and Distribution of Hirola (Beatragus hunteri) in Kenya*. PhD thesis, University of Newcastle-upon-Tyne.

Anderson, E.C., W.J. Doughty, J. Anderson and R. Paling (1979). The pathogenesis of FMD in African buffalo and the role of this species in the epidemiology of the disease in Kenya. *Journal of Comparative Pathology* **89**: 541–550.

Andersson, J.A. and D.H.M. Cumming (2014). Defining the edge: boundary formation and TFCAs in southern Africa. In J. A. Andersson, M. de Garine-Wichatitsky, D. H. M. Cumming, V. Dzingirai and K.E. Giller (Eds.), *Transfrontier Conservation Areas: People Living on the Edge*. London: Earthscan, pp. 25–61.

Anon. (1977). Legal Notice 120. *Kenya Gazette* **79**(22): 330.

Artz, N., B. Motsamai, P. Zacharias and P. Tueller (1991). The Grassland Society of Southern Africa's first international conference. *Rangelands Archives* **13**: 237–239.

Asibey, E.O. (1974). Wildlife as a source of protein in Africa south of the Sahara. *Biological Conservation* **6**: 32–39.

Augustine, D.J., K.E. Veblen, J.R. Goheen, et al. (2011). Pathways for positive cattle–wildlife interactions in semi-arid rangelands. *Smithsonian Contributions to Zoology* **632**: 55–71.

Bauer, H., B. Chardonnet, P. Scholte,et al. (2020). Consider divergent regional perspectives to enhance wildlife conservation across Africa. *Nature Ecology and Evolution* **5**: 149–152.

Beard, P.H. (1977). *The End of the Game: The Last Word from Paradise – A Pictoral Documentation of the Origins, History and Prospects of the Big Game Africa*. New York: Chronicle.

Beechler, B.R., R. Bengis, R. Swanepoel, et al. (2015). Rift Valley Fever in Kruger National Park: do buffalo play a role in the inter-epidemic circulation of virus? *Transboundary and Emerging Diseases* **62**: 24–32.

Bengis, R.G. (2012). Anthrax in free-ranging wildlife. In R.E. Miller and M. Fowler (Eds.), *Fowler's Zoo and Wild Animal Medicine: Current Therapy*, Vol 7. St Louis: Elsevier Saunders Press, pp. 98–107.

Bengis, R.G. and D.G. Grobler (2000). Breeding of "disease free" buffalo. Proceedings of the North American Veterinary Conference, Orlando, FL, 5–19 January 2000, pp. 1032–1033.

Bengis R.G., R.A. Kock and J. Fischer (2002). Infectious animal diseases: the wildlife livestock interface. *Revue Scientifique et Technique de l'OIE* **21**: 53–62.

Bengis, R.G., N.P. Kriek, D.F. Keet, et al. (1996). An outbreak of bovine tuberculosis in a free-living African buffalo (*Syncerus caffer*) population in the Kruger National Park: a preliminary report. *Onderstepoort Journal Veterinary Research* **63**: 15–18.

Brasnett, N.V., R.D. Richmond, G.W. Dimbleby, et al. (1948). Fifth Empire Forestry Conference, 1947: reviews of papers submitted. *Empire Forestry Review* **27**: 83–128.

Büyüm, A.M., C. Kenney, A. Koris, et al. (2020). Decolonising global health: if not now, when? *BMJ Global Health* **5**(8): e003394.

Caron, A., D. Cornélis, C. Foggin, et al. (2016). African buffalo movement and zoonotic disease risk across Transfrontier Conservation Areas, Southern Africa. *Emerging Infectious Diseases* **2**: 277–280.

CBD [Convention on Biological Diversity]. Ecosystem Approach, as endorsed by COP5 of the convention Decision V/6, Principle 4. www.cbd.int/decision/cop/?id=7148

CBD [Convention on Biological Diversity]. Sustainable Use Principles, as accepted by COP7 of the convention Decision VII/12, Principle 13. www.cbd.int/decision/cop/?id=7749

Channumsin, M., M. Ciosi, D. Masiga, et al. (2019). Blood meal analysis of tsetse flies (*Glossina pallidipes*: Glossinidae) reveals a reduction in host fidelity when feeding on domestic compared to wild hosts. *BioRxiv* 69205.

Chigwenhese, L., A. Murwira, F.M. Zengeya, et al. (2016). Monitoring African buffalo (*Syncerus caffer*) and cattle (*Bos taurus*) movement across a damaged veterinary control fence at a Southern African wildlife/livestock interface. *African Journal of Ecology* **54**: 415–423.

Clausen, P.-H., I. Adeyemi, B. Bauer, et al. (1998). Host preferences of tsetse (Diptera: Glossinidae) based on bloodmeal identifications. *Medical and Veterinary Entomology* **12**: 169–180.

Condy J.B. and D.B. Vickers (1972). Brucellosis in Rhodesian wildlife. *Journal South African Veterinary Medical Association* **3**: 175–179.

Dasmann, R.F. (1964). *African Game Ranching*. London: Pergamum Press.

de Garine-Wichatitsky, M., A. Caron, C. Gomo, et al. (2010). Bovine tuberculosis in buffaloes, Southern Africa. *Emerging Infectious Diseases* **16**: 884–885.

De Jong, J.F., P. van Hooft, H.J. Megens, et al. (2020). Fragmentation and translocation distort the genetic landscape of ungulates: Red Deer in the Netherlands. *Frontiers in Ecology and Evolution* **8**: 365.

De Vos, A., G.S. Cumming, D. Cumming, et al. (2016). Pathogens, disease, and the social–ecological resilience of protected areas. *Ecology and Society* **21**(1): 20.

De Vos, V. and P.C. Turnbull (2004). Anthrax. In J.A.W Coetzer and R.C. Tustin (Eds.), *Infectious Diseases of Livestock*, 2nd ed. Oxford: Oxford University Press, pp. 1788–1818.

De Vos, V. and C.A.W.J. van Niekerk (1969). Brucellosis in the Kruger National Park. *Journal South African Veterinary Medical Association* **40**: 331–334.

Dublin, H.T. and J.O. Ogutu (2015). Population regulation of African buffalo in the Mara–Serengeti ecosystem. *Wildlife Research* **42**: 382–393.

Ebedes, H. (1976). Anthrax epizootics in Etosha National Park. *Madoqua* **10**: 99–118.

Empire Marketing Board (1930). *The Dissemination of Research Results Among Agricultural Producers: Answers to a Questionnaire Issued by the Empire Marketing Board*. London: His Majesty's Stationary Office.

Ferguson, K.J., S. Cleaveland, D.T. Haydon, et al. (2013). Evaluating the potential for the environmentally sustainable control of foot and mouth disease in Sub-Saharan Africa. *Ecohealth* **10**: 314–322.

Ferguson, K. and J. Hanks (2010). *Fencing Impacts: A Review of the Environmental, Social and Economic Impacts of Game and Veterinary Fencing in Africa with Particular Reference to the Great Limpopo and Kavango–Zambezi Transfrontier Conservation Areas*. Pretoria: Mammal Research Institute.

Gadd, M.E. (2012). Barriers, the beef industry and unnatural selection: a review of the impact of veterinary fencing on mammals in Southern Africa. In M.J. Somers and M.W. Hayward (Eds.), *Fencing for Conservation: Restriction of Evolutionary Potential or a Riposte to Threatening Processes?* Berlin: Springer, pp 153–186.

Gebretsadik T. (2016). Causes for biodiversity loss in Ethiopia: a review from conservation perspective. *Journal of Natural Sciences Research* **6**: 32–40.

Georgiadis, N.J., F. Ihwagi, J.N. Olwero and S.S. Romanach (2007). Savanna herbivore dynamics in a livestock dominated landscape. II: ecological, conservation, and management implications of predator restoration. *Biological Conservation* **137**: 473–483.

Gifford-Gonzalez, D. (2000). Animal disease challenges to the emergence of pastoralism in Sub-Saharan Africa. *African Archaeological Review* **17**: 95–139.

Glover, B., M. Macfarlane, R. Bengis, et al. (2020). Investigation of *Brucella melitensis* in sable antelope (*Hippotragus niger*) in South Africa. *Microorganisms* **8**: 1494.

Gordon, I.J., H.H.T. Prins and G. Squire (Eds.) (2016). *Food Production and Nature Conservation: Conflicts and Solutions*. London: Routledge.

Gradwell, D.V., A.P. Schutte, C.A.W.J. Van Niekerk and D.J. Roux (1977). The isolation of *Brucella abortus*, biotype1 from African buffalo in the Kruger National Park. *Journal South African Veterinary Medical Association* **48**: 41–43.

Grunblatt, J., M. Said and P. Wargute (1996). *DRSRS National Rangelands Report: Summary of Population Estimates for Wildlife and Livestock, Kenyan Rangelands 1977–1994*. Nairobi: Department of Resource Surveys and Remote Sensing (DRSRS), Ministry of Planning and National Development.

Guerrini, L., D.M. Pfukenyi, E. Etter, et al. (2019). Spatial and seasonal patterns of FMD primary outbreaks in cattle in Zimbabwe between 1931 and 2016. *Veterinary Research* **50**(1): 73.

Guilbride, P.D.L., D.H.L. Rollison and E.G. McAnulty (1963). Tuberculosis in free-living African (Cape) buffalo (*Syncerus caffer*). *Journal Comparative Pathology and Therapeutics* **73**: 337–348.

Gunn, G.H. (1932). Milk supplies, with special reference to legislation. *South African Medical Journal* **6**: 251–256.

HAC (2021). www.hacfornatureandpeople.org/home

Hampson, K., T. Lembo, P. Bessell, et al. (2011). Predictability of anthrax infection in the Serengeti, Tanzania. *Journal of Applied Ecology* **48**: 1333–1344.

Hargreaves, S.K., C.M. Foggin, E.C. Anderson, et al. (2004). An investigation into the source and spread of foot and mouth disease virus from a wildlife conservancy in Zimbabwe. *Revue Scientifique et Technique de l'OIE* 23: 783–790.

Herr, S. and C. Marshall (1981). Brucellosis in free-living African buffalo (*Syncerus caffer*): a serological survey. *Onderstepoort Journal Veterinary Research* **48**: 133–134.

Holdo, R.M., A.R.E. Sinclair, A.P. Dobson, et al. (2009). A disease-mediated trophic cascade in the Serengeti and its implications for Ecosystem C. *PLoS Biology* **7**(9): e1000210.

Homewood, K., P.C. Trench and D. Brockington (2012). Pastoralist livelihoods and wildlife revenues in East Africa: a case for pastoralism. *Research, Policy and Practice* **2**: 19.

Hugh-Jones, M.E. and V. De Vos (2002). Anthrax and wildlife. *Revue Scientifique et Technique de l'OIE* **21**: 359–383.

Keet, D.F., N.P.J. Kriek, R.G. Bengis, D.G. Grobler and A. Michel (2000). The rise and fall of tuberculosis in a free-ranging chacma baboon troop in the Kruger National Park. *Onderstepoort Journal of Veterinary Researc* **67**: 115–122.

Keet, D.F., N.P.J. Kriek, R.G. Bengis and A.L. Michel (2001). Tuberculosis in kudus (*Tragelaphus strepsiceros*) in the Kruger National Park. *Onderstepoort Journal of Veterinary Research* **68**: 225–230.

Keet, D.F., N.P.J. Kriek, M.-L. Penrith, A. Michel, and H.F. Huchzermeyer (1996). Tuberculosis in buffaloes (*Syncerus caffer*) in the Kruger National Park: spread of the disease to other species. *Onderstepoort Journal Veterinary Research* **63**: 239–244.

Kihwele, E.S., M.P. Veldhuis, A. Loishooki, et al. (2021). Upstream land-use negatively affects river flow dynamics in the Serengeti National Park. *Ecohydrology and Hydrobiology* **21**: 1–12.

Kinne, J., R. Kreutzer, M. Kreutzer, U. Wernery and P. Wohlsein (2010). Peste des petits ruminants in Arabian wildlife. *Epidemiology and Infection* **138**: 1211–1214.

Kock, R.A. (2005). What is this infamous 'Wildlife/Livestock Disease Interface?': a review of current knowledge for the African continent. In S.A. Osofsky, S. Cleaveland, W.B. Karesh et al. (Eds.), *Proceedings of the Southern and East African Experts Panel on Designing Successful Conservation and Development Interventions at the Wildlife/Livestock Interface: Implications for Wildlife, Livestock and Human Health, AHEAD (Animal Health for the Environment And Development) Forum*, IUCN Vth World Parks Congress, Durban, South Africa, 14 and 15 September, 2003. Gland: IUCN, pp. 1–13.

Kock, R.A. (2006). Rinderpest and wildlife. In T. Barrett, P.P. Pastoret and W. Taylor (Eds.), *Rinderpest and Peste des Petits Ruminants Virus: Plagues of Large and Small Ruminants*. London: Elsevier, pp. 144–162.

Kock, R.A. (2010). The newly proposed Laikipia disease control fence in Kenya. In K. Ferguson and J. Hanks (Eds.), *Fencing Impacts: A Review of the Environmental, Social and Economic Impacts of Game and Veterinary Fencing in Africa with Particular Reference to the Great Limpopo and Kavango–Zambezi Transfrontier Conservation Areas*. Pretoria: Mammal Research Institute, pp. 71–74.

Kock, R., M. Kock, M. de Garine-Wichatitksy, P. Chardonnet and A. Caron (2014). Livestock and buffalo (*Syncerus caffer*) interfaces in Africa: ecology of disease transmission and implications for conservation and development. In M. Melletti and J. Burton (Eds.), *Ecology, Evolution and Behaviour of Wild Cattle: Implications for Conservation*. Cambridge: Cambridge University Press, pp. 431–445.

Kock, R.A., J.M. Wambua, J. Mwanzia, H. Wamwayi, et al. (1999). Rinderpest epidemic in wild ruminants in Kenya 1993–7. *Veterinary Record* **145**: 275–283.

Kock, R.A., H.M. Wamwayi, P.B. Rossiter, et al. (2006). Re-infection of wildlife populations with rinderpest virus on the periphery of the Somali ecosystem in East Africa. Rinderpest in East Africa: continuing re-infection of wildlife populations on the periphery of the Somali ecosystem. *Preventive Veterinary Medicine* **75**: 63–80.

KWS [Kenya Wildlife Service] (2021). *National Wildlife Census Report 2021.* Nairobi: Ministry of the Environment, Government of Kenya Publisher.

Lankester, F. and A. Davis (2016). Pastoralism and wildlife: historical and current perspectives in the East African rangelands of Kenya and Tanzania. *Revue Scientifique Technique L'OIE* **35**: 473–484.

Lawrence, J.A. (1992). History of bovine theileriosis in southern Africa. In R. A. I. Norval, B. D. Perry and A. S. Young (Eds.), *The Epidemiology of Theileriosis in Africa*. London: Academic Press, pp. 1–39.

Ledger, H.P. (1964). The role of wildlife in African agriculture. *East African Agricultural and Forestry Journal* **30**: 137–141.

Maggs, T. (1986). The early history of the black people in southern Africa. In T. Cameron and S.B. Spies (Eds.), *Illustrated History of South Africa*. Johannesburg and London: J. Ball.

Martínez-Avilés, M., I. Iglesias and A. De La Torre (2020). Evolution of the ASF infection stage in Wild boar within the EU (2014–2018). *Frontiers in Veterinary Science* **7**: 155.

Matseketsa, G., N. Muboko, E. Gandiwa, D.M. Kombora and G. Chibememe (2019). An assessment of human–wildlife conflicts in local communities bordering the western part of Save Valley Conservancy, Zimbabwe. *Global Ecology and Conservation* **20**: e00737.

Mattioli, R.C., V.S. Pandey, M. Murray and J.L. Fitzpatrick (2000). Immunogenetic influences on tick resistance in African cattle with particular reference to trypanotolerant N'Dama (*Bos taurus*) and trypanosusceptible Gobra zebu (*Bos indicus*) cattle. *Acta Tropica* **75**: 263–277.

Metzger, K.L., A.R.E. Sinclair, R. Hilborn, J.G.C. Hopcraft and S.A.R. Mduma (2010). Evaluating the protection of wildlife in parks: the case of African buffalo in Serengeti. *Biodiversity and Conservation* **19**: 3431–3444.

Meunier, N.V., P. Sebulime, R.G. White and R. Kock (2017). Wildlife–livestock interactions and risk areas for cross-species spread of bovine tuberculosis. *Ondersterpoort Journal of Veterinary Research* **84**: 1–10.

Michel, A.L. and R.G. Bengis (2012). The African buffalo: a villain for interspecies spread of infectious diseases in southern Africa. *Onderstepoort Journal of Veterinary Research* **79**: 26–30.

Miescher, G. (2012). *Namibia's Red Line: The History of a Veterinary and Settlement Border*. New York: Palgrave MacMillan.

Miguel, E., V. Grosbois, A. Caron, et al. (2013). Contacts and foot and mouth disease transmission from wild to domestic bovines in Africa. *Ecosphere* **4**: 1–32.

Morris, C.A. (2007). A review of genetic resistance to disease in *Bos taurus* cattle. *The Veterinary Journal* **174**: 481–491.

Mukarati, N.L., G. Matope, M. de Garine-Wichatitsky, et al. (2020). The pattern of anthrax at the wildlife–livestock–human interface in Zimbabwe. *PLoS Neglected Tropical Diseases* **14**(10): e0008800.

Munangándu, H.M., V.M. Siamudaala, A. Mambota, et al. (2006). Disease constraints for utilisation of the African buffalo (*Syncerus caffer*) on game ranches in Zambia. *Japanese Journal of Veterinary Research* **54**: 3–13.

Mureithi, M.M., A. Verdoodt, J.T. Njoka, J.S. Olesarioyo and E. Van Ranstithi (2019). Community-based conservation: an emerging land use at the livestock–wildlife interface in northern Kenya In J.R. Kideghesho and A.A. Rija (Eds.), *Wildlife Management – Failures, Successes and Prospects*. London: IntechOpen, pp. 62–77.

Musoke, J., T. Hlokwe, T. Marcotty, B.J. du Plessis and A.L. Michel (2015). Spillover of *Mycobacterium bovis* from wildlife to livestock, South Africa. *Emerging Infectious Diseases* **21**: 448–451.

Mutwira, R. (1989). Southern Rhodesia wildlife policy (1890–1953): a question of condoning wildlife slaughter. *Journal of Southern African Studies* **15**: 250–262.

Ndengu, M., G. Matope, M. de Garine-Wichatitsky, et al. (2017). Seroprevalence of brucellosis in cattle and selected wildlife species at selected livestock/wildlife interface areas of the Gonarezhou National Park, Zimbabwe. *Preventive Veterinary Medicine* **146**: 158–165.

Neitz, W.O., A.S. Canham and E.B. Kluge (1955). Corridor disease: a fatal form of bovine theileriosis encountered in Zululand. *Journal South African Veterinary Medical Association* **26**: 79–87.

NRT [Northern Rangelands Trust] (2020). State of Conservancies Report Northern Rangelands Trust. www.nrt-kenya.org

Odadi, W.O., M.K. Karachi, S.A. Abdulrazak and T.P. Young (2011). African wild ungulates compete with or facilitate cattle depending on season. *Science* **333**: 1753–1755.

Ogutu, J.O., H.-P. Piepho, M.Y. Said, et al. (2016). Extreme wildlife declines and concurrent increase in livestock numbers in Kenya: what are the causes? *PLoS One* **11**(9): e0163249.

Omondi G., F. Gakuya, J. Arzt, et al. (2020). The role of African buffalo in the epidemiology of foot-and-mouth disease in sympatric cattle and buffalo populations in Kenya. *Transboundary and Emerging Diseases* **67**: 2206–2221.

Paine, R. and G. Martinaglia (1928). Tuberculosis in wild buck living under natural conditions. *Journal South African Veterinary Medical Association* **1**: 87–92.

Poshiwa X., R.A. Groeneveld, I.M.A. Heitkönig, et al. (2013a). Reducing rural households' annual income fluctuations due to rainfall variation through diversification of wildlife use: portfolio theory in a case study of south eastern Zimbabwe. *Tropical Conservation Science* **6**: 201–220.

Poshiwa, X., R.A. Groeneveld, I.M.A. Heitkonig, et al. (2013b). Wildlife as insurance against rainfall fluctuations in a semi-arid savanna setting of southeastern Zimbabwe. *Tropical Conservation Science* **6**: 108–125.

Prins, H.H.T. (1989). East African grazing lands: overgrazed or stably degraded? In W.D. Verwey (Ed.), *Nature Management and Sustainable Development*. Amsterdam/Tokyo: IOS, pp. 281–306.

Prins, H.H.T. (1992). The pastoral road to extinction: competition between wildlife and traditional pastoralism in East Africa. *Environmental Conservation* **19**: 117–123.

Prins, H.H.T. (2000). Competition between wildlife and livestock. In H.H.T. Prins, J.G. Grootenhuis and T.T. Dolan (Eds.), *Conservation of Wildlife by Sustainable Use*. Boston: Kluwer Academic, pp. 51–80.

Prins, H.H.T. and J.F. de Jong (2022). The ecohistory of Tanzania's northern Rift Valley – can one establish an objective baseline as endpoint for ecosystem restoration? In M. Bond, C. Kiffner and D. Lee (Eds.), *Tarangire: Human–Wildlife Coexistence in a Fragmented Landscape*. Cham: Springer Nature, pp. 129–161.

Prins, H.H.T. and F.J. Weyerhaeuser (1987). Epidemics in populations of wild ruminants: anthrax and impala, rinderpest and buffalo in Lake Manyara National Park, Tanzania. *Oikos* **49**: 28–38.

Pruvot, M., A.E. Fine, C. Hollinger et al. (2020). Outbreak of peste des petits ruminants in critically endangered Mongolian saiga and other wild ungulates. *Emerging Infectious Diseases* **26**: 51–62.

ROAPE (Review of African Political Economy) (2022). The struggles of the Ngorongoro Maasai. https://roape.net/2022/02/11/the-struggles-of-the-ngorongoro-maasai/

Robinson, P.A. (2017). Framing bovine tuberculosis: a 'political ecology of health' approach to circulation of knowledge(s) about animal disease control. *The Geographical Journal* **183**: 285–294.

Scholte, P., O. Pays, S. Adam, et al. (2021). Conservation overstretch and long-term decline of wildlife and tourism in the Central African savannas. *Conservation Biology* **36**(2): e13860.

Scoones, I., A. Bishi, N. Mapitse, et al. (2010). Foot-and-mouth disease and market access: challenges for the beef industry in southern Africa. *Pastoralism* **1**: 135–164.

Shiferaw, F., S. Abditcho, A. Gopilo, M.K. Laurenson (2002). Anthrax outbreak in Mago National Park, southern Ethiopia. *Veterinary Record* **150**: 318–320.

Shury, T.K., J.S. Nishi, B.T. Elkin and G.A. Wobeser (2015). Tuberculosis and brucellosis in wood bison (*Bison bison athabascae*) in northern Canada: a renewed need to develop options for future management. *Journal of Wildlife Diseases* **51**: 543–554.

Sintayehu, D.W., I.M.A. Heitkönig, H.H.T. Prins, et al. (2017b). Effect of host diversity and species assemblage composition on bovine tuberculosis (bTB) risk in Ethiopian cattle. *Parasitology* **144**: 783–792.

Sintayehu, D.W., H.H.T. Prins, I.M.A. Heitkönig and W.F. de Boer (2017a). Disease transmission in animal transfer networks. *Preventive Veterinary Medicine* **137**: 36–42.

Swanepoel, H., J. Crafford and M. Quan (2021). A scoping review of virald diseases in African ungulates. *Veterinary Science* **8**: 17.

Swanepoel, R. (1976). Studies on the epidemiology of Rift Valley fever. *Journal South African Veterinary Medical Association* **47**: 93–94.

Thomson, G.R. and D.S. Bastos (2004). Foot and mouth disease. In J.A.W. Coetzer and R.C. Tustin (Eds.), *Infectious Diseases of Livestock*, 2nd ed. Cape Town: Oxford University Press, pp. 1324–1365.

Thomson, G.R., M.L. Penrith, M.W. Atkinson, et al. (2013). Balancing livestock production and wildlife conservation in and around southern Africa's transfrontier conservation areas. *Transboundary and Emerging Diseases* **60**: 492–506.

Tikhonov, A. (2008). *Bos primigenius*. IUCN Red List of Threatened Species. 2008: e.T136721A4332142.

Tjaronda, W. (2008). Namibia: VCF hampers market access. New Era (Windhoek), 14 April 2008. https://allafrica.com/stories/200804140810.html.

Tyrrell, P.R, S. Russell and D. Western (2017). Seasonal movements of wildlife and livestock in a heterogenous pastoral landscape: implications for coexistence and community-based conservation. *Global Ecology and Conservation* **12**: 59–72.

UNEP (2011). *Environmental, Social and Economic Assessment of the Fencing of the Aberdare Conservation Area*. A report for: The Kenya Wildlife Service, Kenya Forest Service, Kenya Forests Working Group, United Nations Environment Programme and Rhino Ark Biotope Consultancy Services: Nairobi.

Valls-Fox, H., S. Chamaillé-Jammes, M. de Garine-Wichatitsky, et al. (2018). Water and cattle shape habitat selection by wild herbivores at the edge of a protected area. *Animal Conservation* **21**(5): 365–375.

Viggers, K.L., D.B. Lindenmayer and D.M. Spratt (1993). The importance of disease in reintroduction programmes. *Wildlife Research* **20**: 687–698.

Vosloo, W., L.-M. de Klerk, C.I. Boshoff, et al. (2007). Characterisation of a SAT-1 outbreak of foot-and mouth disease in captive African buffalo (*Syncerus caffer*): clinical symptoms, genetic characterisation and phylogenetic comparison of outbreak isolates. *Veterinary Microbiology* **120**: 226–240.

Vosloo, W., P.N. Thompson, B. Botha, et al. (2009). Longitudinal study to investigate the role of impala (*Aepyceros melampus*) in foot-and-mouth disease maintenance in the Kruger National Park, South Africa. *Transboundary and Emerging Diseases* **56**: 18–30.

Weaver, G.V., J. Domenech, A.R. Thiermann and W.B. Karesh (2013). Foot and mouth disease: a look from the wild side. *Journal of Wildlife Diseases* **49**: 759–785.

Wekesa, S.N., A.K. Sangula, G.J. Belsham, et al. (2015). Characterisation of recent foot-and-mouth disease viruses from African buffalo (*Syncerus caffer*) and cattle in Kenya is consistent with independent virus populations. *BMC Veterinary Research* **11**: 17.

Western, D., P. Tyrrell, P. Brehony, et al. (2020). Conservation from the inside-out: winning space and a place for wildlife in working landscapes. *People and Nature* **2**: 279–291.

White, P.J., R.L. Wallen, C. Geremia, et al. (2011). Management of Yellowstone bison and brucellosis transmission risk – implications for conservation and restoration. *Biological Conservation* **144**: 1322–1334.

Whittington, R., K. Donat, M.F. Weber, et al. (2019). Control of paratuberculosis: who, why and how. A review of 48 countries. *BMC Veterinary Research* **15**: 1–29.

Woodford, M.H. (1982a) Tuberculosis in wildlife in the Ruwenzori National Park, Uganda (Part 1). *Tropical Animal Health and Production* **14**: 81–88.

Woodford, M.H. (1982b). Tuberculosis in wildlife in Ruwenzori National Park, Uganda (Part 2). *Tropical Animal Health and Production* **14**: 155–159.

Young, A.S. (1981). The epidemiology of theileriosis in East Africa. In A.D. Irvin, M.P. Cunningham and A.S. Young (Eds.), *Advances in the Control of Theileriosis*. Dordrecht: Springer, pp. 38–55.