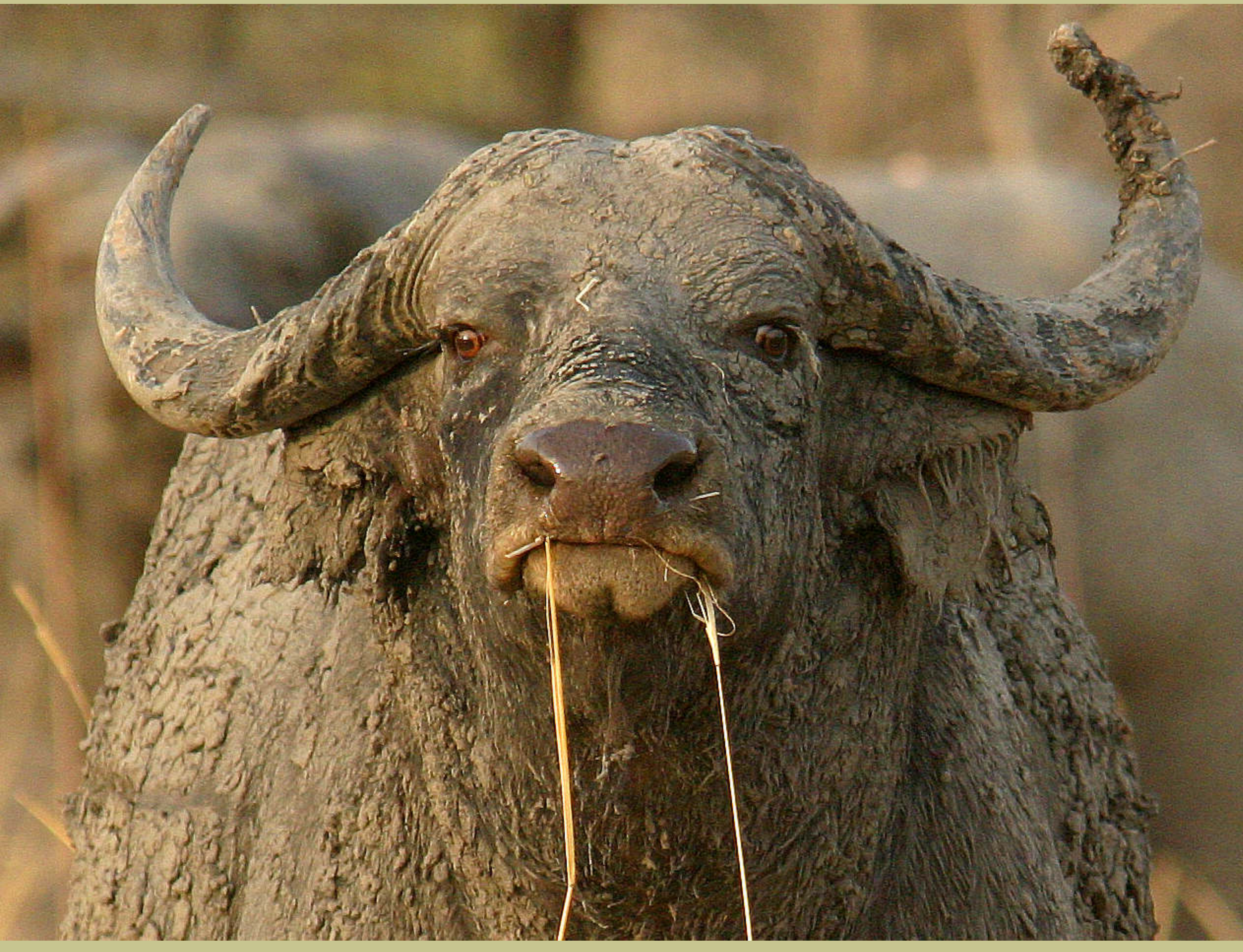
IUCN

SSC
Species Survival Commission

Antelope Specialist Group

Gnusletter

Special Issue Number 1
September 2015



Special Issue - African buffalo

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    - Habitat Selection by African Buffalo (*Syncerus caffer*) in Response to Landscape-Level Fluctuations in Water Availability on Two Temporal Scales. Bennitt *et al.*
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    - Spatial and temporal changes in group dynamics and range use enable anti-predator responses in African buffalo. Tambling *et al.*
    - Spatiotemporal dynamics of forage and water resources shape space use of West African savanna buffaloes. Cornélis *et al.*

- Health
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    - Bovine tuberculosis in Buffaloes, Southern Africa.Garine-Wichatitsky (de) *et al.*
    - Transboundary Conservation Areas, African Buffalo Movements and Animal Diseases. Caron *et al.*

- Genetics
    - Genetic structure of fragmented southern populations of African Cape buffalo (*Syncerus caffer caffer*). Smitz *et al.*
    - Cape buffalo mitogenomics reveals a Holocene shift in the African human–megafauna dynamics. Heller *et al.*
    - Pan-African Genetic Structure in the African Buffalo (*Syncerus caffer*): Investigating Intraspecific Divergence. Smitz *et al.*
    - Influence of habitat fragmentation on the genetic structure of large mammals: evidence for increased structuring of African buffalo (*Syncerus caffer*) within the Serengeti ecosystem. Ernest *et al.*
    - Gene Polymorphisms in African Buffalo Associated with Susceptibility to Bovine Tuberculosis Infection. Roex (le) *et al.*

Portfolio

- Cape buffaloes
- Forest buffalo
- West African savanna buffaloes
- Central African savanna buffaloes
- Handling buffaloes
- Birds & buffaloes

FROM THE EDITORS

Welcome to the GNUSLETTER Special Issue Number 1, which is exclusively dedicated to the African buffalo.

Further to the African Buffalo Symposium, organized by the IGF Foundation in Paris last November, we are pleased to present summaries of all lectures given during this Buffalo Day.

For this special issue, sixteen recent publications on ecology, health and genetics of the African buffalo are presented as summaries. Then, a selection of original publications has also been incorporated in this issue. We greatly thank the authors for sharing their work.

Finally, at the end of this issue, a selection of pictures illustrates the diversity of the four sub-species of the African buffalo.

We are very grateful to Christophe Demichelis for having edited this special issue.

We hope that you enjoy this special issue of GNUSLETTER and encourage you to share widely. Your future contributions are most welcome.

Philippe Chardonnet, David Mallon, Steve Shurter,
Alessandro Fusari, Daniel Cornélis & Alexandre Caron

The IUCN SSC ASG Position Statement on the Intentional Genetic Manipulation of Antelopes Ver. 1.0 (30 April 2015), which also applies to the African buffalo

1. Introduction

The IUCN SSC Antelope Specialist Group (ASG) is concerned by the use of intentional genetic manipulation (IGM) of antelopes to create modified phenotypes such as novel coat patterns or enlarged horns, conducted for amenity, ecotourism, live trade and/or hunting purposes.

ASG fully supports the principle of sustainable use of wildlife and other natural resources, including appropriately managed game ranching and hunting, in accordance with:

- the *Addis Ababa Principles and Guidelines* of the Convention on Biological Diversity, 1992 (https://www.cbd.int/sustainable/addis.shtml);
- the *Policy Statement on Sustainable Use of Wild Living* Resources of IUCN, 2000 (http://povertyandconservation.info/en/biblio/b1391);
- the *Guiding Principles on Trophy Hunting as a Tool for Creating Conservation Incentives* of IUCN SSC, 2012 (http://cmsdata.iucn.org/downloads/iucn_ssc_guiding_principles_on_trophy_hunting_ver1_09aug2012.pdf);
- WCC Resolution 3.093, 2005 *Application of the IUCN Sustainable Use Policy to sustainable consumptive use of wildlife and recreational hunting in southern Africa* (https://cmsdata.iucn.org/downloads/wcc_res_rec_eng.pdf)

2. Definitions of IGM

IGM may comprise:

- Manipulations between taxa:
  - Hybridizing two different species, either indigenous or exotic;
  - Crossing two different subspecies or strains, either indigenous or exotic.
- Manipulations within taxa:
  - Selective inbreeding to exaggerate the prevalence of some characters;
  - Cloning;
- Combinations of manipulations.

3. Purpose and extent of IGM

- The purpose of IGM is to supply private collections, trophy hunting enterprises and other commercial operations and is expanding:
  - Growing in magnitude with a continuously increasing number of (i) facilities involved, (ii) number of antelope species and individuals subject to IGM & (iii) private and public sales;
  - Increasing diversity with a continuously growing number of newly created morphs.
- Antelopes modified by IGM are extensively spread:
  - Most modified antelopes are translocated to other wildlife facilities in or out their original range country or range;
  - IGM antelopes are mostly held behind fences which cannot be regarded as 100% wildlife proof, with a risk of escapes to neighbouring areas including into the wild.

4. Impacts of IGM

The actual and potential impacts of IGM of antelopes comprise:

- Direct threat to biodiversity by risking the survival of indigenous taxa, i.e. genetic pollution by dilution of indigenous taxa;
- Distortion of natural processes of evolution;
- Homogenization of taxa at national or regional scale and globalization of taxa at the global scale;
- Weakened resilience or reduced adaptive capacity to environmental changes, such as health hazards, ecosystem transformation, or climate change;
- Reduced reproductive fitness;
- Other unknown impacts.

5. ASG Statement

The IUCN SSC Antelope Specialist Group:

- Considers that IGM of antelopes incorporates many risks and ignores the precautionary principle;
- States that IGM of antelopes for commercial or amenity purposes makes no contribution to the conservation of biodiversity at global, regional, national and local levels;
- Opposes all IGM of antelopes for commercial or amenity purposes, with particular reference to (i) hybridization of different species, (ii) crossing of different subspecies and (iii) selective inbreeding of a population.

Philippe Chardonnet and David Mallon, Co-Chairs

IUCN SSC Antelope Specialist Group (2015). *IUCN SSC Antelope Specialist Group Position Statement on the Intentional Genetic Manipulation of Antelopes. Ver. 1.0.*

Ecology, Evolution and Behaviour of Wild Cattle

Implications for Conservation

Mario Melletti James Burton

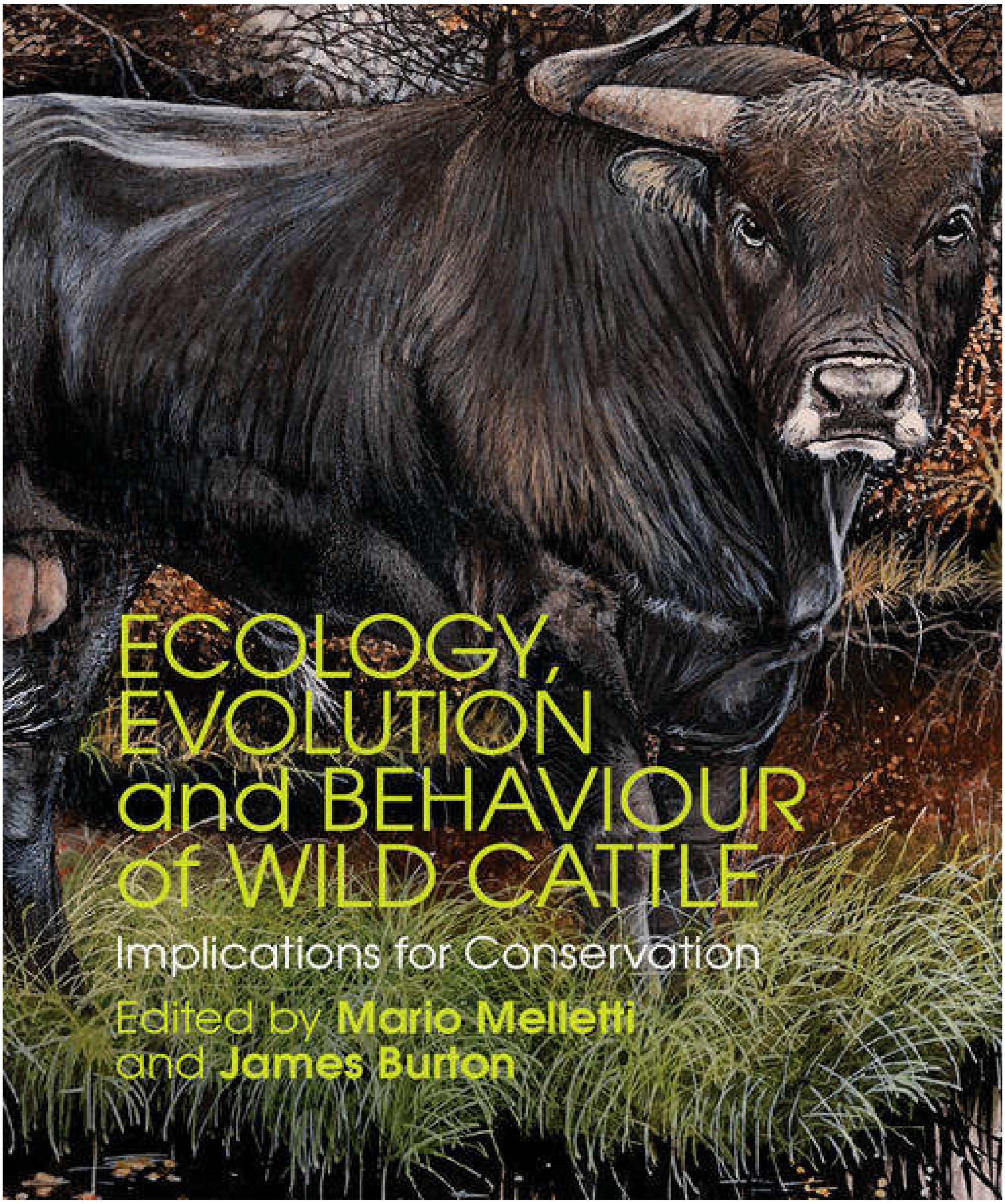
Hardback ISBN: 9781107036642 Published: October 2014

Original Price: £100/$160 Discounted Price: £80/$128 Offer Expires: 31st January 2015

Covering all 13 species of wild cattle, Ecology, Evolution and Behaviour of Wild Cattle brings together the contributions of international leading experts on the biology, evolution, conservation status and management of the tribe Bovini, providing:• A comprehensive review of current knowledge on systematic, anatomy and ecology of all wild cattle species (chapters 1 to 8)• A clear understanding of the conservation status of each species and the gaps in our current knowledge (chapters 9 to 20)• A number of case studies on conservation activities and an investigation of some of the most threatened and poorly understood species (chapters 21 to 27). An invaluable resource for students, researchers, and professionals in behavioural ecology, evolutionary biology and conservation biology, this beautifully illustrated reference work reveals the extraordinary link between wild cattle and humans, the benefits some of these species have brought us, and their key roles in their natural ecosystems.

Contents

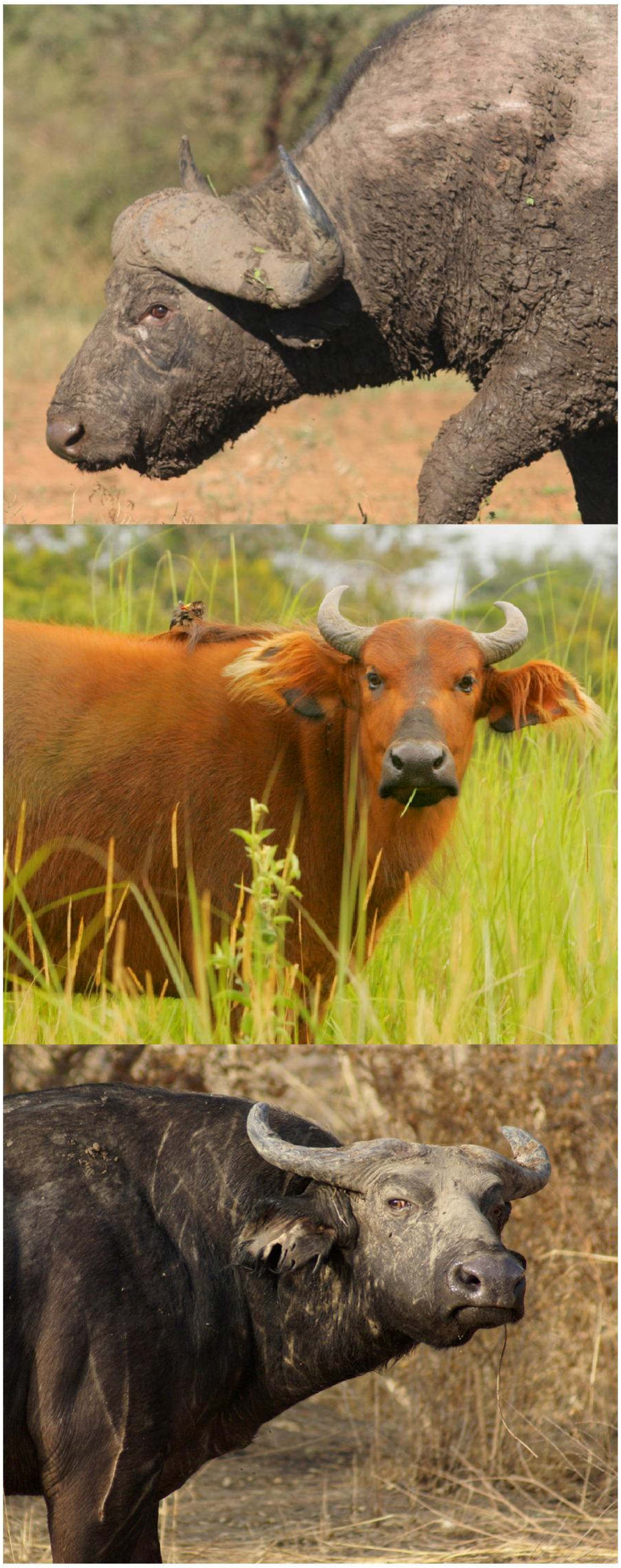
Illustrations: Francesco Rinaldi, Luciano Toma and Enrico Chiarelli; **Distribution maps**: Piero Visconti



SYMPOSIUM

PARIS, 2014

NOVEMBER 5TH AND 6TH



TOP
Cape buffalo
MIDDLE
Forest buffalo
BOTTOM
West African
savanna buffalo

AFRICAN BUFFALO SYMPOSIUM

Under the auspices of the Antelope Specialist Group (ASG Co-chairs : David Mallon and Philippe Chardonnet) of the Species Survival Commission of IUCN, the symposium is organised by the International Foundation for Wildlife Management (Fondation IGF) in collaboration with the CIRAD Research Center (Daniel Cornélis and Alexandre Caron), and hosted by the Fondation François Sommer pour la Chasse et la Nature.

The symposium will report on most recent activities in conservation, management and health of the African Buffalo. Scientific articles, books, other academic results and recent management activities (census, re-introduction, ranching, etc.) will be discussed.

SYMPOSIUM
5TH AND 6TH
NOVEMBER
2014

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INTRODUCTION

The International African Buffalo Symposium was held on November 5th and 6th, 2014, in the auditorium of the François Sommer Fondation pour la Chasse & la Nature, Paris, France.

Placed under the auspices of the Antelope Specialist Group of the Species Survival Commission of IUCN, the symposium was organized by the International Foundation for Wildlife Management (IGF Foundation).

52 participants from 19 countries attended the Symposium. 20 conferences were presented on very different themes such as: ecology, management, health, genetics, conservation and sustainable utilization of natural resources, all disciplines for which the African Buffalo seems to be a key species, even if it is not yet recognized as such.

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Philippe Dulac, President of the François Sommer Foundation (©Olivier Buttin)

FACILITATORS

Philippe Chardonnet (©Olivier Buttin)

Holly Dublin (©Olivier Buttin)

David Mallon (©Olivier Buttin)

Buffalo Dav - Paris - 5^{th} & 6^{th} November 2014

Day	Period	Session	Time	Speaker	Title
DAY 1			08:30-9:00	*Welcome coffee & registration*	
	MORNING	Preamble	09:00-09:15	Philippe Dulac, President of François Sommer Foundation	Welcoming
			09:15-09:30	Philippe Chardonnet	Introduction
		Conservation	09:30-10:00	Richard Kock	African buffalo - a reflexion on pathways to healthy animal harvest and production systems
			10:00-10:20	Mario Melletti	Ecology and conservation of wild cattle throughout the world
			10:20-10:40	Daniel Cornélis et al.	The African Buffalo Database: stepping towards a multi-species web-based platform
			10:40-11:10	*Coffee break*	
		Conservation	11:10-11:40	Peter Oberem	Drivers of the South African buffalo ranching industry
			11:40-12:00	Carlos Bento et al.	The African buffalo: recovery of the species after the civil war in Central Mozambique
			12:00-12:20	Vernon Booth	African buffalo as a commodity species for the hunting industry
			12:20-13:30	*Lunch*	
	AFTERNOON	Ecology	13:30-14:00	Herbert Prins	Is there evidence that African buffalo act as key-stone species?
			14:00-14:20	Lisa Korte	Spatial and social organization of forest buffalo at Lopé National Park, Gabon
			14:20-14:40	Daniel Cornélis et al.	Spatiotemporal dynamics of forage and water resources shape space use of West African savannah buffalo
			14:40-15:00	Thomas Prin et al.	Understanding the mechanisms limiting the buffalo population in Niassa National Reserve, Mozambique
			15:00-15:30	*Coffee Break*	
		Ecology	15:30-15:50	Joseph Ogutu & Holly Dublin	Population regulation of the Serengeti-Mara buffalo
			15:50-16:10	Emily Bennitt	The ecology of Cape buffalo in the Okavango Delta, Botswana
			16:10-16:30	Isaak Lekolool	Highlights on recent research activities in the African buffalo in Kenya
			16:30-17:50	Sadie Ryan	Cape buffalo and savanna seasonality: feeding, breeding, and some notes on the future
			17:50-18:00	Philippe Chardonnet	Ending Day 1
			20:00	*Diner cocktail*	
DAY 2	MORNING	Health & Genetic	09:00-09:20	Nathalie Smitz et al.	New insights on African buffalo genetics
			09:20-09:40	Pim Van Hooft et al.	March of the deleterious gene variants in the African buffalo: effects on population viability
			09:40-10:00	Alexandre Caron et al.	An investigation of social & health dynamics in Cape buffalo, Great Limpopo Transfrontier Conservation Area
			10:00-10:20	Sven Parsons	Controlling bovine tuberculosis in buffaloes: understanding susceptibility and improving diagnosis
			10:20-10:50	*Coffee Break*	
		Synthesis	10:50-11:10	Holly Dublin	Synthesis
		Panel & Debate	11:10-11:50	Panel with speakers	Questions to speakers (facilitator: Holly Dublin)
			11:50-12:30	Dialogue with participants	Debate with participants (facilitator: Holly Dublin)
			12:30-14:00	*Lunch*	
		Closing	14:00-14:30	IGF Foundation & François Sommer Foundation	Movie on buffalo reintroduction to Gile National Reserve, Mozambique: "*Histoire d'un retour*"
			14:30-15:00		Closing remarks

African buffalo - a reflexion on pathways to healthy animal harvest and production systems

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Abstract: African buffalo is a keystone species on the continent and remain critical to the ecological health of grass and bush lands as yet not ravaged by man. Unfortunately they also sit in the likely "extinction box" of the big five, species which appear to be incompatible with modern human landscapes. Buffalo have declined rapidly outside of protected areas, and are vilified by livestock keepers and veterinary establishment. Why is this species condemned by all except the ecotourist and sport hunter who revere it? In evolutionary history buffalo were perhaps the most highly successful ruminant species on the African continent expanding and sustaining grasslands against the constant pressure of vegetation change, through their voracious appetites and crushing hoofs, at least until the arrival of humans and their livestock. Indigenous pastoral peoples, ranchers and settler farmers were all intolerant of the direct competition these bulk grazers presented to livestock systems, both in terms of forage and the infections carried by buffalo that can be so devastating to exotic herds. The reputation of this species as a formidable and aggressive opponent to the hunter and interloper did little to enamour the beast to human communities. Whilst the rarity value and the auction cost to the sport hunters increases in a few countries, what is the likely fate of the buffalo overall? What is the truth about the role of buffalo as a vector of cattle disease and as a constraint on control and economic development of African livestock, and could the species once again play a significant role as an immunological model of health in a pathogen jungle, and as a terrestrial fish providing valuable protein and animal products to the expanding human community whilst still fulfilling its vital ecological role? This paper will discuss.

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Richard Kock, (©Olivier Buttin)

Ecology and conservation of wild cattle throughout the world

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Abstract: This is the first work combining the state of our knowledge of every known wild cattle species. It covers the ecology, evolution, taxonomy, conservation status and management of all 13 species. The layout of the book follows a detailed organisation in four sections consisting of 27 chapters. It begins with Systematic, Ecology and Domestication, followed by Evolution, Anatomy and Function, then Species Accounts and Conservation and Management sections. In the first section of the book is presented: a) the most update information on interspecific relationships and the systematic position of most wild cattle species; b) the impact that some species have in their ecosystems; and c) the domestication process during thousands of years through the world and the benefits that domestic species brought us. In the second section, the main characteristics of some anatomical aspects of *Bovini* are discussed, such as skeletal evolution, mammary glands, digestive system, horns and teeth in the context of evolution and function. In the third section, we present detailed and current data on each species. We review most of the published studies available from the recent past. Each species account is so divided: names; taxonomy; subspecies and distribution; descriptive notes; habitat; movements and home range; activity patterns; feeding ecology; reproduction and growth; behaviour; parasites and diseases; status in the wild, status in captivity and references. In the last section we have arranged a set of accounts, including some case studies, giving an overview on conservation, management, ex situ projects, genetics and disease ecology. Finally, we conclude underlining that most of these species are under severe threats and they need urgent and effective conservation action. If current trends continue many Asian species will become extinct in the near future. We really hope that this work can be a step towards the conservation of this group of amazing species.

Mario Melletti (©Olivier Buttin)

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The African Buffalo Database: stepping towards a multi-species web-based platform

DANIEL CORNELIS[1,3,5*], TARA DANIEL[2], PHILIPPE CHARDONNET[1,4] & HOLLY DUBLIN[2]

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Abstract: As with most African mammals, buffalo populations have undergone a severe reduction in size and geographical distribution since the 19th century. The last known continental abundance and distribution data has recently been updated for a review chapter on African buffalo. Although providing a useful basis for conservation, management and policy making, such updates result from individual or poorly coordinated efforts and give only snapshots with limited potential for analysis and dissemination. The IUCN/SSC African Elephant Specialist Group (AfESG) maintains the African Elephant Database (AED), likely the world's most comprehensive single-species database. As the formal repository of African elephant survey data, the AED, a spatially-enabled web platform, collates data at the site, national, sub-regional, and continental levels, as well as hosts an updated range map for the continent. Inspired by this example, both Antelope and African

Elephant Specialist Groups seek to establish the foundation for ongoing data collection, integration, analysis, and dissemination on African Buffalo, in the framework of a Multi-Species Database (MSD). The MSD presents an unprecedented opportunity to build a platform for conservation decision-making at the landscape-level. This shared platform also has potential for integrating additional species and spatial covariates, supporting the objective of providing integrated, comprehensive syntheses for conservation purposes.

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Drivers of the South African buffalo ranching industry

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Abstrac: Historically, several factors have leaded to the almost total decline of the Cape buffalo (*Syncerus caffer caffer*) outside national and provincial Parks in South Africa, in particular: a) the "great white" hunters, b) the Anglo-Boer War, c) the 1900 outbreak of Rinderpest in Southern Africa, d) the South African Veterinary Services bovine tuberculosis control measures, and e) the ngana and tsetse fly control programmes of the 1950s. Today, however, buffalo numbers and value suddenly increase in South Africa, mainly because of: a) the recognition of private ownership of game through the promulgation of the Game Theft Act, Act 101 of 1991, b) the breeding of "disease-free buffalo", and c) the growth in the rare species and "stud" game breeding industries. The main challenges to the continued growth of the wildlife ranching industry, which presents both conservation and business aspects, are: a) the fragmented disease control policies of the South African Veterinary Services and its lack of capacity, b) the old and outdated environmental legislation, which has been enacted prior to the emergence of the wildlife ranching industry, and c) the opposition from some local hunting groups. The later is mainly against the direction taken by the wildlife ranching industry, mainly because some local hunters groups perceive, incorrectly, that this is making the cost of consumptive hunting too high. It is foreseen that: a) modern technologies (such as genetics and diagnostic techniques), b) "stud" breeding to restore horn length, c) the treatment of diseases (such as corridor disease), d) the vaccination against contagious abortion, and e) a move from the regionally-based to the commodity-based trade policies by the OIE, will add further impetus to this industry and its contribution to both the South African economy and conservation.

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Peter Oberem (©Olivier Buttin)

The African buffalo: recovery of the species after the civil war in Central Mozambique

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Abstract: Armed conflicts result in large scale extirpation of wildlife due to land mines and through direct bush meat hunting by soldiers and refugees. Disorders created by armed conflicts also lead to

conditions conducive for poaching. Together with the African elephant, the African buffalo (*Syncerus caffer*) was significantly poached during the civil war in Mozambique. In the present study, historical data from Marromeu Reserve and Gorongosa National Park in Central Mozambique provided a unique opportunity to assess factors that influenced the survival of African buffalo populations before, during, and after the armed conflict. Our analysis showed that the presence of extensive and continuous areas of papyrus swamp provided a refuge that allowed the survival and growth of the African buffalo population in the Marromeu Reserve in recent years. The presence of a buffer zone with proper management practices by the hunting operators was also important in the maintenance of African buffalo populations in Marromeu Reserve. During the armed conflict, the African buffalo population retracted its range during the dry season to the papyrus swamps, a habitat providing water, food, and hardly accessible to poachers. In recent years, these favourable conditions led to an increase in population density and a gradual expansion of the African buffalo distribution range, including the surrounding miombo woodland. The situation in Gorongosa National Park however is different. Despite a re-introduction plan, the African buffalo population is growing slowly compared to the Marromeu Reserve. These results suggest that the landscape and favourable conservation management practices are important factors in the recovery and survival of the species in post-conflict situations. From a conservation point of view, it is crucial to create a buffer area, with proper conservation management around the protected area in order to minimize the external factors that may negatively influence the wildlife core population.

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African buffalo as a commodity species for the hunting industry

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Abstract: The African buffalo (*Syncerus caffer*), is regarded as one of the classic 'Big Five' trophy species that are highly coveted by the sport hunting industry. The distribution of buffalo across range states offering sport hunting and the numbers available place a high demand on this species as a trophy commodity. This demand influences the manner in which fees are charged to secure this trophy and how the industry markets buffalo safaris. This latter aspect plays a pivotal role on the financial viability and economics of the safari hunting industry. As a result of this, those involved in managing safari operations will go to great lengths to secure access to buffalo through purchasing live animals, breeding

Vernon Booth (©Olivier Buttin)

disease free herds, travelling within the region to areas where buffalo can be hunted and paying considerable fees to secure hunting blocks that support viable buffalo populations. This in turn places pressure on administrators of hunting areas to ensure that buffalo, as a commodity, are not underpriced in the market and that quotas are managed sustainably to ensure long-term trophy quality and age. This requires that administrators apply the best practices to ensure that this trophy species retains is value to the sport hunting industry. The threats to buffalo, as a commodity to the hunting industry, are to be found on many fronts. The most prevalent is from disease, and the threat of foot and mouth disease in the livestock industry, the threat of illegal hunting to supply the bushmeat trade, loss of habitat and more recently genetic engineering by breeders geared to pander to the record books. Mitigating against these requires a thorough understanding of the importance of buffalo to the industry.

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Is there evidence that African buffalo act as key-stone species?

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Abstract: Some species within the *Bovini* have important ecological functions but there is only scant evidence that they act as key-stone species. From an analysis of the ecological literature it is clear that water buffalo can act as key-stone species in Australia where it is an introduced species but there is no evidence that it is a key-stone species in its native range. American bison and yak clearly functioned as key-stone species, and so do the descendants of the aurochs. Of the African buffalo we know that it can form a very large part of the ungulate biomass, but is there evidence that it functions as a key-stone species?

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Spatial and social organization of forest buffalo *(Syncerus caffer nanus)* at Lopé National Park, Gabon

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Abstract: Forest buffalo (*Syncerus caffer nanus*) occur throughout the Congo Basin Forest region of central Africa. Unlike for the well-studied Cape (or savanna) buffalo (*S.c. caffer*), few data exist for forest buffalo. Here, I examine habitat use and group size of forest buffalo at Lopé National Park, Gabon. Distance analysis of habitat use from radio-tracking data was used to assess forest buffalo habitat selection at two spatial scales. At the landscape scale, buffalo selected savanna and marsh habitat over forest habitat. Thus, forest buffalo home ranges were savanna-dominated despite the greater amount of forest habitat available in the overall landscape. At the scale of the home range (2.30 km^2 to 7.64 km^2), habitat selection within home ranges varied with season. Adult female forest buffalo preferred forest habitat between March and August but preferred marsh to forest between September and February. Forest buffalo dwell in forest habitat, feed in savannas, and wallow in marshes, utilizing all habitat types in the landscape. I also examine variation of group size of forest buffalo. Eighteen forest buffalo herds used the study area with

an estimated population of 342 individuals (~ 5 buffalo/km^2). Mean group size for the 18 herds was 12 ± 2 (range of means = 3-24), considerably smaller than Cape buffalo herds. For eight radio-collared forest buffalo, mean group size was stable, varying little with time of day, across seasons, or between savanna and marsh habitat. However, herd size varied widely across herds, from fewer than ten individuals in the smallest herds to more than 20 buffalo in the largest. Large herd size is associated with home ranges that contain substantial areas of open habitat, and thus more food resources than forested habitats.

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Lisa Korte (©Olivier Buttin)

Spatiotemporal dynamics of forage and water resources shape space use of West African savannah buffalo

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Abstract: We investigated space-use patterns of the West African savanna buffalo (*Syncerus caffer brachyceros*), a little-studied subspecies occurring at the northern limit of the African buffalo's geographical range. This buffalo generally ranges in small herds (about 45 individuals) and has a low body mass (approximately 400 kg) relative to the Cape buffalo (*S.c. caffer*). We monitored the movements of 7 breeding herds in "W" Regional Park (Burkina Faso, Benin and Niger) using GPS collars and activity data loggers. Habitat selection was analyzed at both large (inter-seasonal) and small (intra-seasonal) scales in a context where resources are segregated spatially at some times of year. Both biotic (primary production, vegetation types) and abiotic (timing of rainfall, surface water) covariates, and the extent to which neighbouring herds shared space, were considered. In the dry season buffalo herds ranged close (within 5.3 ± 2.0 km, Mean ± SD) to segments of permanent rivers. At the onset of the monsoon all herds but 1 (which had year-round access to suitable resources) performed a large (35 ± 10 km) directional response to a large-scale gradient of primary production. Spatiotemporal dynamics of orage and water resources thus jointly stimulated inter-seasonal directional movements and shaped large (335 ± 167 km²) annual home ranges. Furthermore, the establishment of home ranges in the wet season appears to be conditioned by a threshold (about 10%) in the availability of perennial grasses. Habitat selection analysis at intra-seasonal scale also underlined the key role played by perennial grasses for buffaloes. The spatial arrangements of home ranges of neighbouring herds also suggest that inter-herd behavioural avoidance is a high-level constraint on foraging processes. The ability of the African buffalo to cope with contrasting environmental conditions throughout most sub-Saharan ecosystems highlights the high behavioural plasticity of this species.

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Understanding the mechanisms limiting the buffalo population in Niassa National Reserve, Mozambique

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Abstract: The Niassa National Reserve (NNR), Mozambique is one of the vastest protected areas in Africa (42,140 km^2) and includes around 39,000 local residents within the limits of the reserve. NNR suffered from 10 years of independence war (1964-1974) and 15 years of civil war (1977-1992), during which wildlife population decreased substantially. Despite important conservation efforts, the density of ungulate community remains strikingly low compared to other similar savanna systems, especially buffalo which is considered as a key asset for the local trophy hunting industry and has logically become a management priority for the NNR. We addressed this issue through three main protocols. First, we investigated data from 5 aerial surveys (2002-2011) to explore relationships between buffalo distribution and environmental covariates at the end of the dry season, a period reflecting large scale and long-term equilibriums with key resources. Second, we investigated space use and habitat selection strategies at annual and seasonal scales by GPS tracking the movements of 9 buffalo herds in contrasted areas over 3 years. Third, we assessed the potential direct and indirect impacts of household's livelihood on buffalo and natural resources using questionnaires in contrasted villages. Results show that both the spatial arrangement of permanent rivers and residual water in seasonal tributaries strongly drive buffalo distribution within NNR in the dry season. Home range sizes were among the largest on record for the species with large seasonal movements in response to segregated resources. Bushfires appeared to strongly constrain habitat selection and the magnitude of their extension to greatly limit the availability of forage for buffalo. No obvious avoidance of human activities (villages/road proximity) was observed by the first two protocols, but responses to the questionnaires suggest a potentially severe impact of poaching on buffalo population dynamics. Results provide valuable information for wildlife managers. At such a large scale, due to the heterogeneity of environmental covariates, management actions must be adapted to the contrasting zones within NNR.

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Population regulation of African buffalo in the Mara-Serengeti ecosystem

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Abstract: The processes regulating ungulate populations have been the focus of numerous studies. For the African buffalo population inhabiting the Mara-Serengeti ecosystem, rinderpest was the primary regulatory factor up to the mid 1960s. Following reduction of rinderpest and buffalo population increase, interspecific competition for food, notably with cattle and wildebeest, was thought to be the

primary regulatory factor in the ecosystem. We analysed buffalo population trend and the relationship between buffalo population growth and rainfall in the Mara-Serengeti ecosystem and discuss the findings in the context of buffalo population dynamics in African savannas. We analysed buffalo population dynamics in the Mara-Serengeti ecosystem in relation to rainfall during 1984-2010. Buffalo population growth was both significantly density dependent and positively correlated with the dry season rainfall after, but not before, a severe drought in 1993. Buffalo numbers crashed by 48.6% in 1984/85 and by 76.1% in 1993/94 during severe droughts when food availability was lowest and competition with the more numerous cattle and wildebeest highest. Recovery of buffalo numbers to pre-drought levels took 8-9 years after the 1984/85 drought but was much slower, with buffaloes numbering merely 36% of their 1993 population (12,895 animals) 18 years after the 1993/94 drought despite intermittent periods of high rainfall, probably due to demographic and/or reproductive factors, heightened competition with livestock, land use changes in the adjoining pastoral ranches, lion predation and recurrent droughts. Our findings demonstrate how food limitation caused by droughts associated with the hemispheric El Niño-Southern Oscillation can cause severe declines in and threaten the persistence of large ungulate populations. The findings also portray how density-dependent food limitation, land use changes, competition and other factors can accentuate the effect of droughts and greatly prolong population recovery.

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The ecology of Cape buffalo in the Okavango Delta, Botswana

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Abstract: Flood-pulsed ecosystems such as the Okavango Delta, Botswana, experience fluctuations in water availability on several temporal scales. Seasonal variations in water flow cause predictable changes in the profitability of habitats in tropical ecosystems, to which animals evolve adaptive behavioural and spatial responses. However, stochastic changes in the distribution and abundance of surface water between years can alter resource availability at a landscape scale, causing shifts in animal behaviour. In the Okavango Delta, the volume of water entering the system doubled between 2008 and 2009, creating a sudden change in the landscape. We tested the hypotheses that Cape buffalo (*Syncerus caffer caffer*) would select seasonal habitats in relation to water availability, that increased floodwater levels would decrease forage abundance and affect habitat selection, and that this would reduce buffalo recruitment rate and body condition. Buffalo selected habitats far from permanent water during the rainy season and seasonally-flooded habitats close to

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permanent water during the early and late flood seasons. The 2009 water increase reduced forage availability in seasonally-flooded habitats, removing a resource buffer used by the buffalo during the late flood season, when resources were most limited. Buffalo used drier habitats in 2009 and their recruitment rate decreased, but their body condition increased, a possible fat-storing mechanism in anticipation of future resource limitation. Stochastic annual fluctuations in water levels, predicted to increase as a result of anthropogenically-induced climate change, are likely to have substantial impacts on the functioning of water-driven tropical ecosystems, affecting environmental conditions within protected areas. The distribution and relative abundance of habitat types could be affected by climatic changes, pushing animals outside of protected areas and increasing the likelihood of human-wildlife conflict. Buffer zones around critical seasonal resources are essential to allow animals to engage in compensatory behavioural and spatial mechanisms in response to changing environmental conditions.

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Highlights on recent research activities in the African buffalo in Kenya

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Abstract: In Kenya, wildlife is the major product of tourism accounting for about 90% of the Safari tourism and 75% of the total national tourism earnings. Safari tourism is majorly boosted by the presence of the big five species which include Elephant, Rhino, Buffalo, Lion and Leopard found in most of the conservation areas of the country. The African buffalo (*Syncerus caffer*) in Kenya is loved and hated in equal measures. It is one of the big five species in Kenya making it one of the most sought after tourism attraction for Safari tourists while on the other side they are a source of human wildlife conflict in some areas. There have been some few studies some of which are ongoing to establish the disease epidemiology that affect buffaloes and those that may be of economical importance to the country. Foot and mouth disease (FMD) is a notifiable disease in Kenya and ongoing studies in some parts of the country have indicated that the African buffalo may be a reservoir of some of the strains affecting the livestock sector. Bovine tuberculosis (BTB) has been reported to cause deaths of Cape buffalo in South Africa and ongoing studies are being conducted to establish the prevalence of the disease in the wildlife livestock interphase in parts of Kenya. Bovine papillomatosis has been reported in some of the buffalo populations in parts of Kenya with the cutaneous wart papilloma type being the most prevalent.

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Cape buffalo and savanna seasonality: feeding, breeding, and some notes on the future

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Abstract: We examined the role of the changing landscape across seasons in Cape buffalo (*Syncerus caffer caffer*) body condition and indicators of nutrition in Kruger National Park, and upon birth seasonality and timing in neighbouring Klaserie Private Nature Reserve. In this South African savanna environment, buffalo are subject to nutrient availability that fails to meet their base metabolic requirements in the same season as the most energetically expensive part of life-history – gestation and lactation. We found that a protracted gestation period exists for Cape buffalo, and that buffalo select for higher quality vegetation at both small (Klaserie) and large scales (Kruger landscapes), measurable using the Normalized Difference Vegetation Index (NDVI). Given that these Cape buffalo are restricted in movement by their water dependence, and have adapted their life history and habitat use to accommodate extremes of seasons, we suggest that thoughts on the future of African buffalo take into account the impending imposition of climate change and its concomitant variation in seasonality and resource timing on their landscape.

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New insights on African buffalo genetics

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Abstract: Along with the elephant and the wildbeest, the African buffalo (*Syncerus caffer*) is the most dominant species in terms of biomass but also the most widespread herbivore. It exhibits extreme morphological variability at large geographical scale, which has led to controversies about its taxonomic status. Nowadays, the African buffalo experience a severe reduction in population size and geographical distribution, as a result of human demographic expansion, overexploitation, habitat degradation and diseases. Using different kinds of markers on a large sampling set, we aimed to infer the genetic diversity

and phylogeographic history of the African buffalo at the pan-African spatial distribution (N=766), as well as to assess the genetic health and the population structure of southern African Cape buffalo populations that face gene flow restriction (N=264). Analyses highlighted the existence of two distinct lineages at the continental scale: West and Central African populations (*S.c. nanus*, *S.c. brachyceros*, *S.c. aequinoctialis*) and East and Southern African populations (*S.c. caffer*). The two lineages likely expanded and diverged in the late to middle Pleistocene from an ancestral population located around the current-day Central African Republic. They probably adapted their morphology to colonize new habitats, hence developing the variety of ecophenotypes observed today. The finer scale axis-concentrated on southern Africa allowed identifying three genetic clusters. The splitting period suggests that the current pattern results from human-induced factors and/or from the aridification process that occurred during the Holocene. Lower differentiation estimates were observed between localities that experienced translocation over the last century. The two main clusters displayed high intra-cluster genetic diversity, low inter-cluster differentiation, and an absence of inbreeding depression signal, while the third one- a tiny population enclosed within an isolated protected area, experienced genetic drift. All those information are particularly essential within the context of conservation programs currently undertaken to restore genetic diversity of African buffalo populations.

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March of the deleterious gene variants in the African buffalo: effects on population viability

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Abstract: Recently we have shown that many autosomal alleles (gene variants on regular, i.e. non-sex, chromosomes) deleterious to body condition are under positive selection in the African buffalo (*Syncerus caffer*) of Kruger National Park, South Africa. Probably hundreds of genes are involved. We were able to detect positive selection by analysing statistical associations between body condition and specific microsatellite (a commonly used genetic marker) alleles. Furthermore, the deleterious alleles were also statistically associated with a specific Y-chromosome profile, which has been shown to be linked to a sex-ratio suppressor gene. Consequently, we hypothesized that positive selection is driven by a Y-chromosomal sex-ratio suppressor which suppresses a female-biased sperm sex ratio and which is activated by low body condition. A sex-ratio suppressor prevents fertility reduction in males that generally accompanies sperm sex-ratio distortion. Positive selection is possible as long as the increase in male relative fertility is larger than the decrease in male mating success due to low body condition. In other words: male buffalo with relatively low body condition have the highest reproductive success. Here, we studied whether these deleterious alleles also occur in other buffalo populations from East and Southern Africa. We observed a highly significant cline

(correlation between latitude and allele frequency) of deleterious alleles between South Africa and Kenya. Frequencies of deleterious alleles steadily decrease (adjusted R^2 = 0.88, 19 populations) from 45% in Kruger to 20% in Kenya; a distance of 2700 km (about 1% per 100 km). We hypothesize that the sex-ratio suppressor, i.e. the selective agent, originated in South Africa relatively recently, probably no more than 2000 years ago, and has since been spreading north. The enrichment of buffalo populations with alleles deleterious to body condition probably has a negative effect on population viability and increases susceptibility to infectious diseases, amongst others bovine tuberculosis.

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An investigation of social dynamics in Cape buffalo and implications for disease transmission at wildlife/domestic interfaces in the Great Limpopo Transfrontier Conservation Area

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Abstract: In southern Africa, TransFrontier Conservation Areas (TFCAs) are promoting the sustainable coexistence between Mankind and Nature, and are seeking to find a balance between wildlife conservation, agricultural production and natural resource use. In these TFCAs, the various land use

types include wildlife/domestic interfaces prone to create human/wildlife conflicts. Amongst those conflicts, disease transmission between buffalo and cattle (and potentially to human for zoonoses) is a serious concern. In this study, we GPS-tracked buffalo and cattle herds in the Great Limpopo TFCA in order to understand disease transmission and estimate the risk of emerging pathogen spillover. This protocol makes it possible to investigate inter-species contacts along multiple spatiotemporal windows, and thus risks of transmission of various pathogens. Regarding buffalo specifically, Adult females were shown to range within stable home ranges, displaying little overlap with adjacent buffalo herds. However, inter-individual association patterns strongly challenged the standard concept of herd. Interestingly, two of the young GPS-tracked females displayed long-range (70-90kms) movements in a few week times, linking distant buffalo populations across communal lands. This shed light on a poorly described behaviour that has major implications in disease ecology in the GLTFCA. We conclude by discussing the implication of buffalo/cattle interactions for disease transmission, particularly in the context of transboundary disease transmission and by listing some hypotheses that will require testing in the near future to manage the health issue at buffalo/cattle interfaces in Africa.

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Controlling bovine tuberculosis in buffaloes: understanding susceptibility and improving diagnosis

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Abstract: African buffaloes are highly susceptible to infection by *Mycobacterium bovis* and are a major reservoir of this pathogen which causes bovine tuberculosis (BTB) in numerous species. Many lines of evidence, including gene association and gene expression studies, have demonstrated that host genetics plays a role in the outcome of mycobacterial infection in both humans and animals. We have established a DNA biobank from approximately 1000 buffaloes of known *M. bovis* infection status from the Kruger National Park (KNP) and Hluhluwe iMfolozi Park, South Africa, and have investigated the association between genetic single nucleotide polymorphisms and infection status. Such information might inform the breeding of animals with greater resistance to BTB. Also, in order to simplify the diagnosis of *M. bovis* infection, we have investigated the modification of a human TB test, the QuantiFERON-TB Gold assay, and using interferon-gamma (IFN-γ) as a diagnostic biomarker, the assay might be a useful alternative to the tuberculin skin test. However, in its current format the assay appears to be less sensitive than the commercially available Bovigam assay. Alternative diagnostic targets such as mRNA and the protein IP-10 show promise as more sensitive biomarkers of infection. Furthermore, rapid blood-based tests are currently being evaluated as screening tools for BTB in buffaloes. Preliminary data suggests that chronically infected animals are more likely to be seropositive to antigens such as MPB83: in *M. bovis* culture-positive buffaloes from the KNP, 18/26 animals (69.2%) were seropositive in the Chembio STAT-PAK assay and 11/12 (91.7%) reacted in the Bovid DPP test. Since animals that are chronically infected are more likely to have higher mycobacterial loads and develop pathological lesions, serological assays may be useful in detecting those ndividuals that are potentially infectious. Together, these studies aim to identify optimal strategies for the investigation and control of BTB in buffaloes.

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Debate with speakers (©Olivier Buttin)

Participants of the African Buffalo Symposium (©Olivier Buttin)

Update on buffalo in the Volcanoes NP, Rwanda

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The Volcanoes National Park, in Rwanda has overcome the 1990-1994 Rwandan civil war in much better shape than the Akagera National Park in the East of the country (Plumptre, 1997). Population density estimates obtained directly after the war by Plumptre & Harris (1995) for the Karisoke Research Area resulted in >200 buffaloes within the Park. A reassessment of the Park in 1996 revealed a stable buffalo population with a similar estimate as obtained in 1995 (Plumptre & Bizumuremyi, 1996). During the next eight years the newly formed Rwanda Development Board (RDB), now in charge of Rwanda‟s wildlife, focused on the conservation of mountain gorillas and the improvement of livelihoods of the communities living adjacent to the Park.

Not before 2004 another survey attempted to establish the number of buffalo roaming the VNP. Two methods of fecal counting were used, i.e., the standing crop count and the marked pellet group count. Circular plots of 10 m radius were searched intensively at sampling points equally distributed over different vegetation types in nine sectors of the Virunga Massif. A crude population estimate correcting for dung production rates and decay in different seasons, vegetation types and altitudes resulted in an overall estimate of 959 buffaloes in VNP (Owiunji, 2004). Four years later, a large mammal survey was conducted in five sectors of VNP (Tuyisingize, 2008). A marked pellet group count was identified as the best method for surveying buffalo in the Virunga Volcanoes, and the total number of buffaloes was estimated for eight prevailing vegetation types, resulting in a total estimate of 612 buffaloes in the Park. The most recent survey was carried out in 2010, attempting to determine population size and density based on marked pellet group counts in twenty 5x10 m plots in each of seven habitat types (Arakwiye, 2010). The study revealed a mean population density of 0.88 buffalo/km^2, corresponding to an overall population estimate of 141 buffaloes in the entire VNP. 141 buffaloes in the entire VNP.

After instability in Rwanda had ceased, the number of buffaloes in the VNP seems to have steadily decreased. Surprisingly, decreasing buffalo numbers led to increasing human-wildlife conflict around the Park, particularly in 2007/08 when the number of human-buffalo conflict incidences sharply increased from 10 per year to more than 40 (Kalpers et al., 2010). Inherently, buffaloes have always been the most regular problem animals around VNP (Plumptre et al., 2004; Ngaboyamahina, 2004; Ndimukaga, 2006; Ndagijimana, 2009), but in recent years conflict with other wildlife has decreased while conflicts with buffalo has increased (Kalpers et al., 2010; Gray & Rutagarama, 2011). The increase in crop-raiding incidents seems to be in contradiction with the most recent wildlife survey showing an actual decrease in the buffalo population, at least at the local level in the Karisoke area (Arakwiye, 2010). Moreover, people reported that crop raiding by buffalo occurs more often during the dry season, perhaps at a time when food resources inside the Park are scarce.

The construction of a buffalo wall around PNV in 2002 was expected to solve the conflict and to stop buffaloes leaving the Park and destroying people‟s crops. In 2007 the wall was completed and 76 km, i.e., the whole perimeter of the park was wall-fenced (Kwizera & Ndayisaba, 2009). By 2009, with the digging of a trench on the inside of the wall, the incursion of buffaloes into farmland was further reduced along priority sections of the boundary. After 2007, four community associations were established, each being in charge of the wall and trench maintenance in the four most delicate sectors (i.e., Gahunga, Nyange, Kinigi and Shingiro; Kwizera & Ndayisaba, 2009).

For several years, preliminary discussions have been held regarding a possible “extension” of VNP and the creation of a buffer zone. The extension would cover about 3,500 hectares and would basically be a strip of land going all around the park boundary, with varying depth and the least impact in terms of numbers of people to be displaced. The extension could act as a natural barrier for wildlife, through a combination of non-palatable plant species, thorny shrubs and adequate land use (Kalpers et al., 2010). Moreover, it is expected that the implementation of a buffer zone would further improve the attitude of local communities towards the Park. Such social infrastructure projects create more awareness, can impact on more people about conservation issues, and help to improve their attitudes towards the Park (Bush et al., 2010). The buffalo wall, for example, was considered very beneficial by 66%, beneficial by

15%, little beneficial by 15% and not beneficial by only 4% of the persons interviewed (Bush et al., 2010).

Problem animals such as elephants, gorillas and buffaloes represent the main reason for negative attitudes of communities towards protected areas. On the other hand, it is interesting to note that the issue of crop-raiding was only raised by a few respondents during a survey conducted near Bwindi Impenetrable NP in Uganda (Sandbrook, 2006). There seems to be a clear link between benefits received by the community and the perception to human wildlife conflict issues. Similarly, a socio-economic survey carried out around PNV in Rwanda concluded that crop raiding by buffaloes ranked only as a secondary issue raised by the communities interviewed (Bush et al, 2010).

In our most recent survey on the level of involving local communities in park management and conflict resolution around VNP (Kabega et al., 2013), we conducted an interview survey in four sectors (incl. the three most notorious sectors Nyange, Kinigi, and Shingiro) of Musanze District, including 121 randomly selected interviewees of different origin, gender, age, educational level and occupation. We investigated the general perception towards the park, the awareness of the current community conservation program, the persisting problems between wildlife and the community, and the degree of participation in park activities and cooperatives.

Our study showed that the general perception of local communities towards the park has further improved and can be considered as „very good". For example in Nyange Sector up to 80% of interviewed community members stated their relationship with park is „good", while less than 10% claimed to have a „bad" relationship with the park. A large percentage (90-100%) of all people interviewed was well aware of the existing community conservation program. This positive attitude was also reflected by the generally high level of participation. A majority of people was, is or wants to be engaged in park management and conflict resolution.

In our study we also asked question regarding human-wildlife conflict, i.e. what are the most raided crops in relation to the degree of farming and what species is the most destructive? Irish potatoes (60%) and maize (31%) seem to be the most favoured crops throughout all sectors visited. Pyrethrum and sorghum on the other hand, seem to be less preferred by wild animals and therefore represent potential crops to be planted in the envisaged buffer zone. Most interesting was the decrease in crop raiding compared to previous studies (Bush et al., 2010). Elephants, bushbuck and black-fronted duiker were not mentioned at all, while golden monkey and gorillas were increasingly retained within the Park boundaries. Buffalo, however, continued or even increased (Bush et al., 2010) to be the major problem species around the VNP (Figure 1). Across sectors, more than 70% of the interviewed people claimed to have had negative experience with buffalo, either by direct impact or by destroying their crops. This is somehow worrying since this species had received most attention and resources to contain it within the protected area (e.g. buffalo wall, trench). On the other hand this may reflect an increase in buffalo densities in VNP and neighbouring Parc National de Virunga (DRC) and Mgahinga NP (Uganda). It was noted by the current Chief Park Warden in VNP that considerable number of buffaloes migrate between the protected areas and the on-going instability in Eastern DRC may drive the animals into Rwanda. The issue of buffalo migrations between the three protected areas was also addressed in Owiunji"s et al. (2004) study and deserves further research and attention.

However, the VNP could function as a role model for other African national parks due to its excellent conflict resolution management and the extremely generous and tolerant approach of the Rwandan government and NGOs towards the problems of the local community.

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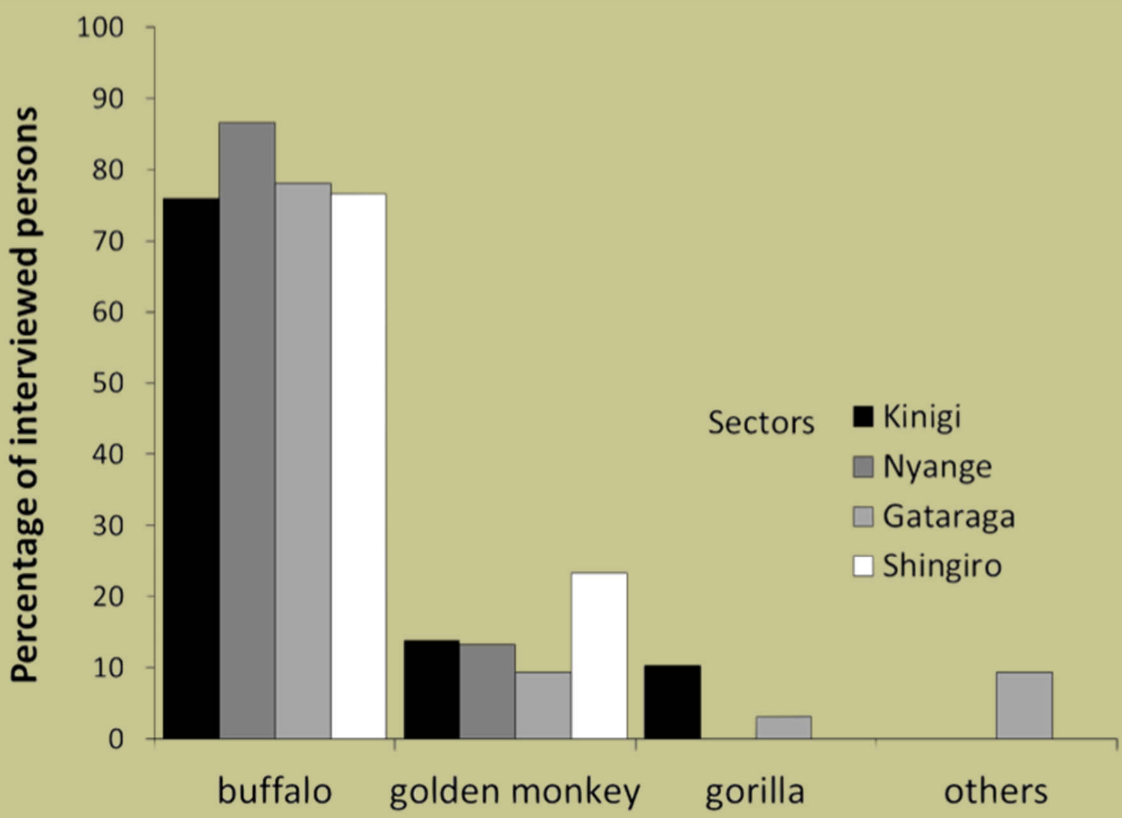

Figure 1. *Percentage of people interviewed that claim to have had bad experiences with buffalo, golden monkey, gorilla or any other species. One hundred and twenty-one interviewees were randomly drawn from four sectors bordering the Volcanoes NP, Rwanda.*

Status of buffalo in Akagera National Park

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The impact of the 1994 civil war on wildlife in Rwanda was dramatic, but most devastating in the Akagera NP. As a consequences of the Rwandan civil war two third of the park were devoted to grazing for around 0.7 million cattle of refugees returning from Uganda and Tanzania in 1995, reducing the park area from 2,500 to 732 km^2 (Kanyamibwa 1998). Information on wildlife in Akagera following the instability of the late 1990's is based on reports by Chardonnet (1995), Chardonnet & East (1995), Lorch (1995) and the comprehensive surveys of Williams & Ntayombya (1999,2001), Lamprey (2002) and Viljoen (2010). Total populations of larger herbivores had decreased by 75-80% between 1990 and 1998 (Williams & Ntayombya 1999, 2001). For about ten years the park rested in agony until in September 2010, a board consisting of Rwanda Development Board (RDB) and African Parks (AP) representatives was appointed and the Akagera Management Company (AMC) was founded. When the AMC took over, management and law enforcement were a challenge due to understaffed ranger force and a lack of resources. Since 2012, the AMC collaborated with RDB, police and Rwanda Defense Force (RDF) in improving the law enforcement of the park. This increased the number of arrested poachers and lead to the removal of thousands of snares.

During that period, the degazetted areas of the former Akagera NP were still frequently used by wild animals and human-wildlife conflict was increasing. People lost lives, crops were destroyed and domestic livestock was competing with wild herbivores for limited resources in a semi-arid environment. In an attempt to reduce human-wildlife conflicts around the new Akagera NP, RDB launched the park from cattle and poacher encroachment. The 110 km long fence along the western boundary of Akagera NP was completed in June 2013 and comprises of a 1.8 m high line of metallic posts crossed by 8 horizontal electrified wires. Before the fence was closed off, RDB and AMC, had to relocate the wildlife that remained outside the fence by driving mostly the larger species (buffalo, zebra, topi) into the park.

Prior to the civil war, buffalo numbers in Akagera NP were estimated to be around 10,000 individuals (Vande weghe & Dejace 1991). In 1998 Williams & Ntayombya (1999, 2001) reported a total of 2,260 buffaloes in the area, whereby only 680 were estimated for the new Akagera NP, but 1,580 for the degazetted parts, underlining the above mentioned human-wildlife conflict. Later, Lamprey (2002) estimated the number of buffalo in the new Akagera NP to be 309, and after launching the AMC in 2010, Viljoen (2010) established the population size of buffalo at 882 individuals. In 2010, Apio & Wronski (2011) counted the larger antelope species in the Park, but due to low encounter rates their study did not include the African buffalo. In 2011 and 2012, two further counts were conducted; also resulting in only a few buffalo encounters and no reliable estimate could be obtained. Thus, count results of all three surveys were pooled to achieve a robust estimate for the combined time period (2010-2013). The resulting estimate was based on road strip counts carried out along nine count routes following the existing park roads. Each route traversed only one of three habitat types (riverine forest, woodland slopes, open grasslands) defined by Williams & Ntayombya (1999). Flood plains were not surveyed using the road strip method, but instead two point counts were carried out to cover the northern flats (*i.e.*, Kilala Valley). Route length varied between 13.0 and 27.7 km, covering all terrestrial areas of the park. For each buffalo encounter the perpendicular distance was determined, using a range finder. All surveys were carried out by two observers during the early morning from 06:00 h to 11:00 h and in the late afternoon between 15:00 h and 18:30 h.

Using the software DISTANCE 6.0, nine different detection function models were tested, *i.e.* a combination of three key functions (uniform, half-normal, hazard-rate) and three adjustment terms (cosine, simple polynomial, hermite polynomial; Thomas et al. 2010). Choosing the best fitting detection function model was based on i) the shape of the curve describing the probability of detecting animals in relation to the recorded perpendicular distances, ii) the lowest AIC (Akaike Information Criteria) value, and the highest chi-square goodness-of-fit (Thomas et al. 2010). To further explore the data set, perpendicular distances were truncated at 200 m and 300 m, and detection function models were rerun. All models truncated at 200 m had the lowest AIC values, but bad detection function fits. Best fitted detection function model was cosine/half-normal, truncated at 300 m with an effective strip width of 70 m.

Additionally, an aerial survey was carried out from 16 to 18 August 2013 (total flight time: 20.3h; MacTherson, 2013), using a Robinson R44, four seat, helicopter with one observer on each side and one additional front seat observer. The basic method applied was a transect count, running east-west across the new Akagera NP with transects spaced at 750 m intervals. A strip width of about 375 m to each side of the transect line was assumed, attempting a minimum total count of the protected area. In total 98 transects of varying length were used to cover all terrestrial parts (app. 405 km^2), excluding lakes and swamps, adding up to a total length of roughly 700 km. Particularly in the northern part of the Park it was often required to divert from the transect route due to uneven terrain (MacTherson, 2013). The helicopter was flown at an altitude of 60-90 m above ground, with a mean speed of 74 km/h. To reliably establish the size of large herds, spot photographs were taken and individuals were counted later. Due to the nature of the count (minimum total count), no methods of analysis were used to further explore the data. Both surveys (ground, aerial) did not include the parts of the former Akagera NP and therefore represent population estimates for the new Akagera NP only.

The estimate obtained from three ground surveys (31 encounters) resulted in a population size of 5,395 buffaloes with a 95% confidence interval of 2,053. This translates into a buffalo density of 13.3 individuals/km^2. Mean group size was determined as 31.7 (95% CI: 12.4) animals. The aerial count resulted in a total of 2,093 buffaloes encountered in 94 groups, plus three herds (120 animals) not seen but known to occur in a forest area not visible from the air. This corresponds to a buffalo density of only 5.48 individuals/km^2 and a mean group size of 22.3 individuals.

Population estimates obtained from aerial and ground survey differed considerably. This may be attributed to the low encounter rate of buffaloes during the ground counts (and the pooling of three consecutive years), resulting in a general overestimation of population size. On the other hand aerial surveys tend to underestimate true population sizes due to the relatively high speed, the flight height and observer fatigue. The application of DISTANCE 6.0 and the random generation of the best fitted model generate reliable data if ground survey assumptions are met. Since this was not guaranteed, a bias towards a higher population size is likely and the true value may be found between the aerial count (2,213 individuals) and the estimate obtained from ground counts (5,395 individuals). In summary, to date population size of buffalo inside the new Akagera NP is as high, or higher than that estimated in 1997/98 by Williams & Ntayombya (1999, 2001) for settled area and new park combined. In 2010, after the AMC was founded the number of buffaloes inside the park was estimated to be 882 animals (Viljoen, 2010). This implies that herds previously inhabiting the degazetted parts have been depleted while numbers inside new Akagera NP have recovered to a level as high as that established in 1997/98 for the entire area. However, a total of about 350 buffalos were driven into the current Park area after the western boundary fence was put in place in June 2013. Improved management, decreased poaching and a lack of lion as an apex predator in the Park coupled with adequate food, water and cover led to near-perfect breeding conditions for the species and therefore steadily increasing numbers.

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Movements of African buffalo (*Syncerus caffer*) in the Kavango-Zambezi Transfrontier Conservation area

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We have been monitoring movements of African buffalo (*Syncerus caffer*) in Namibia and surrounding areas of Botswana and Angola since 2007. Our study area is at the geographic heart of the Kavango-Zambezi Transfrontier Conservation area (KAZA), the world's largest protected area complex at ~440,000 km^2, comprising parts of Namibia, Botswana, Angola, Zambia, and Zimbabwe. The aims of the study are to examine movements, migrations and space use of buffalo in relation to anthropogenic features (roads, fences, settlements, and agricultural areas) as well as the natural spatial and temporal environmental heterogeneity of the region. Since the aims of KAZA are to conserve biodiversity and enhance rural livelihoods via increased wildlife-based tourism, it is critical to determine whether the current patterns of wildlife connectivity are sufficient to see through this vision, while simultaneously assessing the threats that might impede it. Although our investigations began with buffalo and this is the focus here, our larger research group has been monitoring movements of a wide variety of other species, including lion, leopard, wild dog, spotted hyena, crocodile, elephant, Burchell's zebra, and blue wildebeest.

To-date we have deployed satellite tracking collars on 35 individual free-ranging buffalo, with GPS readings set at 5-hour intervals. In addition, we have collected genetic data from over 100 animals across the length of the Namibian part of the study area (to assess how the historical connectivity of buffalo populations compares to current estimates from collar data), and have also conducted disease testing on a similar number of animals (for bovine tuberculosis and foot-and-mouth disease). Our GPS dataset currently includes ~80,000 animal locations (from 30 females and 5 males). We ultimately deployed the majority of collars on females in part because we were mostly interested in breeding herd movements, and in part because those we did attach on bulls were quickly destroyed, probably due to the high frequency of rubbing and fighting in males relative to females.

We have now published several quantitative, peer-reviewed articles using these data (Naidoo et al. *PLoS ONE* 2012; Naidoo et al. *Landscape Ecology* 2012; Epps et al. *Molecular Ecology* 2013), with others to follow. For the purposes here, we focus on three additional qualitative aspects of our work that are relevant to conservation planning and wildlife management in KAZA: (1) Cross-border movements; (2) Effects of linear boundaries – fences, roads, rivers – on movements; and (3) Extremely long-range migratory or dispersal events.

Cross-border movements

Our data show repeated cross-border movements in several locations from Namibia into Angola and Botswana, and vice-versa (Figure 1). Along the Kwando river and westwards (Figure 1, "A"), 9 animals moved regularly from Namibia to southern Angola, during the wet season generally travelling along the well-developed *omuramba* systems (fossil drainage lines between sandy dunes that contain ephemeral water holes) that run roughly northwest-southeast in this area, and moving north-south along the Kwando and its floodplains during the dry season. Similar dry season movements among 4 individuals occurred alongside the Kwando from Namibia into northern Botswana and back, while in the wet season, these animals exploited a 30 km gap in the border fence to range across large areas of the NG14 concession that lies east of the northern buffalo fence in Botswana (Figure 1, "B").

At the eastern tip of Namibia's Zambezi region, buffalo are largely constrained to a small area of floodplain and woodland habitat, but we did document one male buffalo that moved across the Chobe river and headed due south into the Chobe National Park in Botswana, before the signal from the collar was lost (Figure 1, "C"). However, collaborators from Elephants Without Borders (a Botswana-based conservation group) have recently seen the animal (identifiable from its ear tag) on the Chobe floodplains in Botswana, indicating it is still in the vicinity.

Finally, at the other geographical extreme two individual buffalo collared in October 2012 (our most recently tagged animals) have both moved from the Buffalo Core Area of Bwabwata National Park into southern Angola, in the case of one animal, almost 60 km north into the Luengué Hunting Reserve (Figure 1, "D"). In addition, there are anecdotal observations of buffalo crossing the tar road east of Kongola and moving north from Mudumu National Park through a large and relatively intact state forest towards Zambia (Figure 1, "E"). GPS data from wildebeest and elephant confirm Namibia-Zambia cross-border movements in this same location, making the conservation of this forest and wildlife corridor a high priority, given it is the only documented locality of cross-border movements from Namibia to Zambia.

These results demonstrate the importance of transboundary wildlife management, since populations of buffalo are clearly moving throughout the larger region without regard to national borders. A regional, collaborative approach to wildlife conservation is therefore imperative among the KAZA countries, to ensure these shared natural resources are sustainably managed for ecological coherence and maximum livelihood benefits.

Impact of linear boundaries

None of the linear boundaries in our study area were totally impenetrable by buffalo, but they all had observable impacts on movement. For both rivers and fences, we documented only one crossing of each barrier type. Space use and seasonal movements were constrained by the Kwando, Kavango, and Linyanti/Chobe rivers, with these water bodies acting as strong barriers that defined the edges of seasonal home ranges. Fences were also very strong boundaries, with movements of animals clearly impeded by fences in the western part of the Caprivi Strip, the northern buffalo fence in Botswana, and the Namibia-Botswana border fence. Given the strong constraints placed upon movements of animals by fences, the 30 km gap in the border fence west of the Kwando river is of utmost significance in facilitating connectivity between northern Botswana and the large hinterlands of Angola and Zambia to the north, via Namibia. Efforts currently underway to remove a larger section of this fence will likely result in enhanced connectivity in this area. Despite these strong general effects of fences, a female herd animal (red circle, with dashed line indicate approximate route during period when collar signal was lost) was able to penetrate the Namibia-Botswana border fence, presumably through a gap made by elephants, on her way to the Okavango Delta (Fig.1, "F").

Roads had an ambiguous impact on buffalo movements. In certain areas (i.e., Buffalo Core Area, Susuwe, Mudumu National Park), animals regularly crossed either tar highways or gravel secondary roads, while in others (the large middle area of the Caprivi Strip, communal lands north of Mamili National Park), roads apparently acted as a surprisingly strong boundary to movement. It is as yet unclear whether this variation in crossing behavior is due to differences in individual animals' behavior, or to systematic differences in road characteristics, such as vehicle and non-motorized traffic, and/or associated settlements and cultivations alongside the road. We intend to address these questions in a forthcoming study. For the moment, we note the increasing threat of growing settlements alongside major rivers in the study area that impede buffalo access to dry-season resources such as drinking water and floodplain grazing lands. Therefore in addition to conserving cross-border movements and longer-range migrations (see below), maintaining seasonal connectivity between dry and wet season habitats is a critical element of wildlife management in this region.

Finally, in Mudumu National Park, the northern boundary of the park itself and the eastern boundary of Sobbe conservancy appeared to constrain buffalo movements, even though there are no roads or fences in these areas (Figure 1, "G"). This may indicate that buffalo are aware of the increased danger from human hunting when they leave the park, raising the possibility that unseen pressures, especially surges in poaching such as is currently being experienced in the Kavango and Zambezi regions of Namibia, may act to constrain animal movements as much as physical barriers do.

3. Long-range migration and dispersal

We have observed several long-range movements of buffalo that are likely to rank among the longest documented distances for this species anywhere in Africa. In terms of migratory events (i.e., return movement between geographically-separate seasonal home ranges), two years of data from a female collared on the Kwando river floodplains in the dry season of October 2010 (yellow circle) showed that in year 1, she moved 87 km west down the Caprivi Strip before returning to her dry season range, a round trip journey of >170 km. The next year, she again moved almost exactly 87 km during the wet season, but this time south into Botswana, before returning to the same dry season range for a different >170 km journey. Furthermore, a female collared on the Kwando river floodplains in the dry season (pink circle) travelled > 100 km west down the Caprivi Strip, and despite being closer to the Kavango river, began returning to her Kwando dry season range before dying, a return trip that would have been over 200 km.

We have also observed two long-range apparent dispersal events (i.e., permanent movements to a new home range). In the first, a female collared in October 2010 on the Kwando river floodplains (cyan circle) moved over 110 km west down the Caprivi Strip during the wet season before moving back to the floodplains in the dry season of 2011. The following wet season, the animal wandered throughout the NG14 concession area in northern Botswana before dispersing to a dry season habitat in 2012 along the Selinda Spillway in northern Botswana. During the next wet season (2012/2013) the animal ranged over a large chunk of northern Botswana before settling in the Okavango Delta, where her collar was finally removed in late 2013…almost two and a half years after her last visit to Namibian soil. We estimate this animal has walked over 7500 km in Namibia and northern Botswana during the 3 years she was collared.

The second long-range dispersal event involved a female collared in the Buffalo Core Area of Bwabwata National Park in October 2010 (red circle). After a first year of moving relatively small distances within the Buffalo Core Area, in the wet season of 2012/2013 she moved over 100 km east down the Caprivi Strip before retracing her steps and finding a break in the Namibia-Botswana fence. Penetrating into Botswana in February 2013, she eventually made her way down into the Okavango Delta, a further ~100 km (Figure 1, dashed red line indicates approximate displacement during time GPS unit was not transmitting), where she remains at the time of writing in January 2014. Total displacement of this individual buffalo is therefore well over 200 km from point of collaring in Namibia to the current location in Botswana. Given the distances, difficulties, and obstacles encountered along the way, these two dispersal events indicate what appears to be a strong attraction of the Okavango Delta for animals collared along both the Kwando and Kavango rivers in Namibia. Restoring this natural connectivity between the Delta and hinterlands in Namibia and beyond would be strongly facilitated by the removal of the Namibia-Botswana border fence, a plan currently under discussion by both governments.

Perhaps the most remarkable long-range movements we observed came not from GPS data, but rather from animals that were ear-tagged in Mahango National Park in October, 2010, and managed to leave the park animals from various sources suggest they moved as a group along a well-developed *omuramba* from northeastern Botswana into Khaudom National Park, which retains a tiny remnant buffalo population (Figure 1, "H"). At this point, the animals split into two groups, with one group spotted in Angola near the Kavango river, around 250 km from where they had been ear-tagged (white dashed line). Another ear-tagged animal was eventually shot over a year later in an agricultural area in the Otjozondjupa Region in central Namibia (gray dashed line). This location was a mind-boggling 500 km from where she was tagged, far outside what is considered current buffalo range in Namibia; the nearest buffalo are in Nyae Nyae communal conservancy in northeast Namibia, which contains a population of disease-free animals in a fenced compound near Tsumkwe (Figure 1, "I"). Both Khaudom and the buffalo compound in Nyae Nyae are "buffalo legal" areas under the new Animal Disease Act promulgated in 2013.

Our research suggests that despite impediments, the capacity of buffalo for long-range dispersals and migrations has been underestimated, and therefore significant areas in KAZA and beyond may have potential for recolonization if land use policies that designate huge areas as buffalo-free zones are changed. We suspect that continued research on our study populations will reveal further insights into the movement ecology of African buffalo, with implications for transboundary management, conservation, and policy in the Kavango-Zambezi Transfrontier Conservation area and beyond.

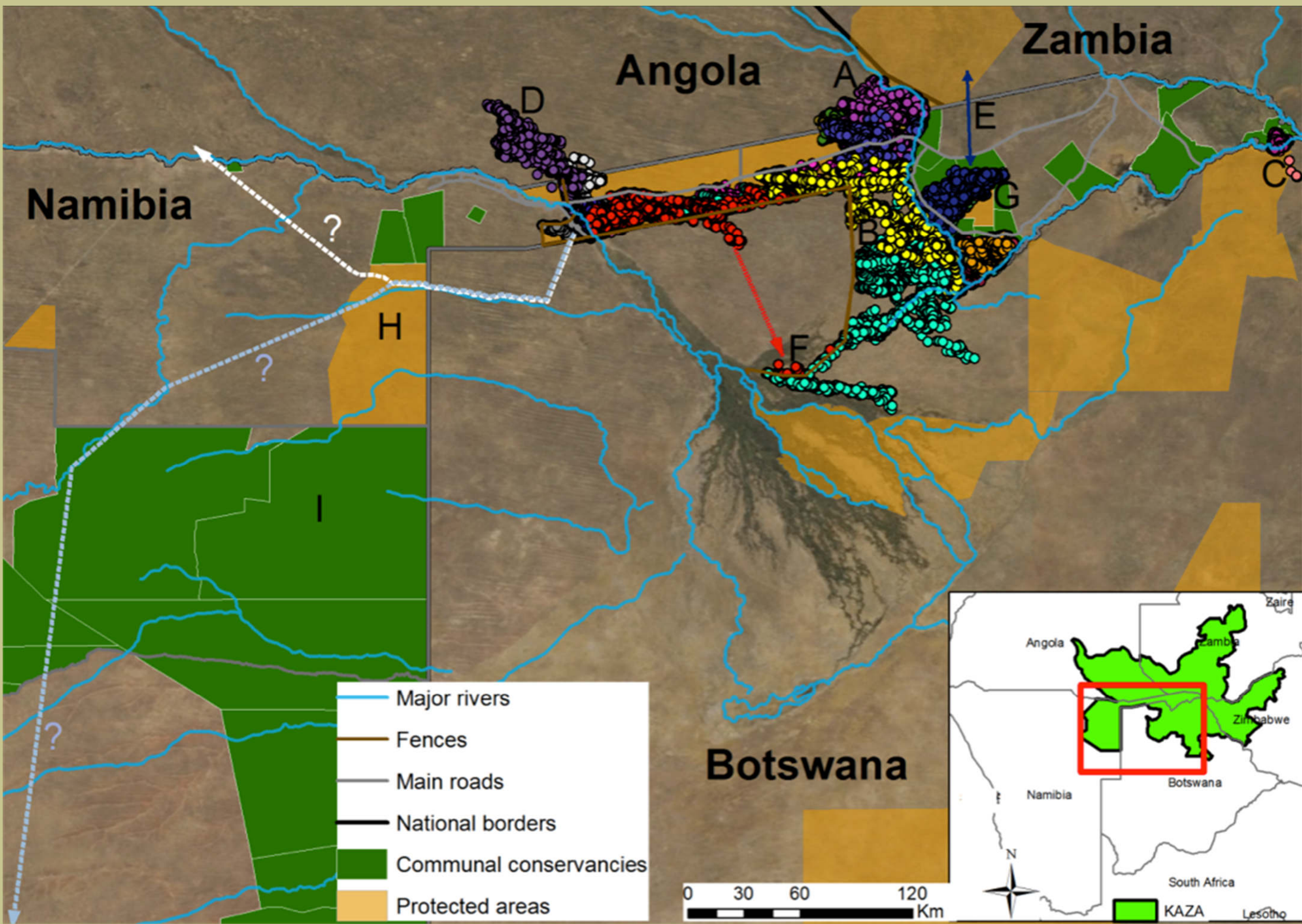

Figure 1. *GPS locations (~ 80,000) for 35 adult buffalo collared in the Kavango and Zambezi regions of Namibia during 2007 – 2014. Colours represent separate individuals. Refer to text for descriptions of symbols A-I and for meaning of dashed and double-headed lines.*

Drivers of the South African Buffalo Ranching Industry

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1. Historical aspects

When the first white settlers landed in the Cape of Good Hope in 1652 the Savanna Buffalo (African Buffalo), *Syncerus caffer caffer*, were found in large numbers in much of Africa south of the Sahara mainly in the savannah and open grassland areas including along the southern coast of South Africa as far west as Swellendam[1].

A number of factors then began eroding their numbers including:

Settlers and hunters

The settlers in the Cape were, initially at least, dependent mainly on livestock for survival. This is amply illustrated by the fact that in South Africa between 1904 and 1930 small stock numbers reached 60 million while cattle numbers also swelled. To put this in perspective there are today less than 25 million small stock in the whole country (with 8 more provinces)[7].

Hunting of the extraordinarily rich variety of Cape wildlife was one of the essential skills for settler survival, and it was used to clear land, reap income, and provide meat so that slaughter of domestic animals could be avoided[6]. These practices and the view that game animals competed with domestic stock for grazing led to a heavy toll on game numbers.

Fences and an ending of the practice of “kraaling” were propagated during the 1870s by Banford, the first Cape Colonial Veterinarian and his successor, Hutcheon, to combat wireworm infestations amongst other diseases in settler livestock[6]. This began to limited the free movement and natural migration of game animals across the country.

The “great white” hunters such as WDM Belllater known as “Karamojo” Bell, Scottish born elephant hunter; P.J. Pretorius; John Henry Patterson (author) and who killed the Tsavo Man-Eaters; Frederick Roberts, 1st Earl Roberts Lord Roberts, Chief of Scouts in the Anglo Boer known as: "England's American Scout"; Bror von Blixen-Finecke who was, between 1914 and 1926, married to "Out of Africa" author, Karen Blixen; Denys Finch Hatton who was, after her marriage collapsed, Karen Blixen's lover; Frank M. "Bunny" Allen, whose safaris with Ernest Hemingway led the author to write "Green Hills of Africa", "True at First Light", "The Short Happy Life of Francis Macomber”, and "the Snows of Kilimanjaro"; Theodore Rooseveld, US President who travelled and hunted in Africa following his terms in office, Frederick Selous after whom the Selous Scouts of Zimbabwe were named; Peter Hathaway Capstick, American hunter who spent most of his life in Africa and many others must together with the advancing settlers have greatly reduced the numbers of game animals in their path. The pre-rinderpest retreat of *Glossina morsitans* in various regions of South Africa and Zimbabwe has been attributed to the big game hunters and the advance of settlers from the south[2].

The outbreak of Rinderpest in Southern Africa

The thriving African buffalo population was brought close to extinction by the rinderpest epidemic which swept southwards through the continent in the 1880s (eventually reaching the Cape in 1898) destroying in its path an estimated 95% of the continents buffalo population and countless thousands of other antelope species. It is estimated that only 10 000 buffalo survived the epidemic in small pockets that did not come into contact with the virus. This viral disease pandemic also, through the decimation of the wild game population, led to the disappearance of tsetse, at least for a period of time, from South Africa[3].

War

The three year 2nd Anglo-Boer War, (1899 to 1902) war further took its toll on game numbers mainly due to the scorched earth policy followed by the British in response to the guerrilla tactics of the grossly outnumbered Boers. In summary, 22 000 British troops killed as were 7 000 Boer commandos, while 28 000 Boer civilians were killed or died in concentration camps. More than 107 000 black people were interred of which ¼ died. Kitchener’s scorched earth policy decimated not only the Boer and black populations as well as their livestock but also the wildlife of the country.

The South African Veterinary Services bovine tuberculosis control measures

From the 1930’s the South African Veterinary Services bovine tuberculosis control measures were centred on testing livestock and culling of animals that tested positive. The eradication of game, especially buffalo was part of this policy[4].

The nagana and tsetse fly control programmes of 1928 to 1960[4]

The tsetse fly and nagana slowly returned as game and livestock numbers grew after the rindepest pandemic and the war. By 1905 nagana had returned to Zululand. Tsetse fly which transmit the blood parasite responsible for nagana were again by the 1920s considered a threat to livestock while game animals served as a reservoir for the trypanosome blood parasite. There were 2 schools of thought about the control of the vector and the disease which was a threat to livestock in the then Natal and eastern Transvaal lowveld: those who advocated the control of the vector, the tsetse fly, and those who advocated the destruction of the reservoir hosts, namely the slaughter of wildlife. Even the Natal Parks Board authorized the large-scale slaughter of all game except the white rhinoceros outside the Umfolozi game Reserve and a thinning out of game within the park (today it is known that excluding the rhino, preferred host, played a significant part in maintaining the tsetse fly). During these sad years most game animals in Zululand area were destroyed[4]. Specific examples given are:

a. Between May 1929 and November 1930 (18 months) 26 000 animals were killed around Umfolozi.

b. Between the end of August 1959 and the end of January 1960 (4 months) some 8000 head of game, mainly warthog, wildebeest, zebra and impala were destroyed.

In Zimbabwe, too, the number of wild animals were reduced by hunting between parallel fences 16 km apart.

Bovine tuberculosis (BTb)

Bovine tuberculosis has been diagnosed in Buffalo in KNP, Umfolozi, and Hluhluwe[5] and more lately in Marakele in the North-West of the country.

Factors which saved the species from extinction in South Africa and led to the restoration of their numbers:

The formation of National- and Provincial Parks

The controversial President S.J. Paul Kruger was a great lover of Africa's wildlife and nature. On 13th June, 1894 he proclaimed the first game Reserve in Africa, Pongola, in the district of Piet Retief in what is now KwaZulu Natal Province of South Africa. On 26th March, 1898 he proclaimed the Sabi Game Reserve in the eastern Transvaal which today as an expanded park carries his name, the Kruger National Park (KNP). These parks were the first steps in conserving South Africa's natural heritage in government parks and reserves, while outside the parks the decimation continued.

Thus, outside these parks, by the middle of the 20th century the future of wildlife conservation in Southern Africa was bleak, so much so that rural properties were advertised with the "advantage" of not having wildlife that would compete with livestock for grazing. At this time, all wildlife in South Africa was *res nullius* and consequently belonged to no one (the State).

Skinner[1] put the number of buffalo in Limpopo and Mpumalanga including the KNP and adjacent private game reserves at only 25 000 animal. In addition, he described 7 separate populations in KwaZulu- Natal, "mainly" in national parks, the biggest being 3 000 animals in the Hluhluwe-Imfolozi Park and a "relic" population of some 280 animals in the Addo National Park in the Eastern Cape. This latter very small population was the only "disease free" buffalo herd in South Africa.

The recognition of private ownership of game

The promulgation of the Game Theft Act, Act 105 of 1991, which confirmed ownership of game was probably the single biggest driving factor for the growth of the game ranching industry in South Africa. With this Act, game gained value and became thus an asset to the (land)owner so consequently game animals became managed as such. Initially, as so few "disease free" buffalo existed in Africa (only from Addo Elephant Park) the impact of ownership and growth in numbers of buffalo was limited.

Disease free breeding schemes

The National Parks Board (SANParks) decided in 1997 / 1998 faced with rapidly spreading bovine TB in KNP buffalo began a project to breed "disease free" buffalo[8] and in so doing conserve the threatened Kruger Genotype and also supply other National Parks with "disease-free" buffalo of the Kruger genotype. Buffalo are known carriers of foot-and-mouth disease (FMD), bovine tuberculosis (BTb), corridor disease and brucellosis. A long-term breeding project was born involving multiphase testing and a breeding scheme for buffalo where after 10 years produced, a sustainable number of buffalo herds, both private and are now available that are free of these four diseases. These buffalo are generally referred to as "disease free" buffalo. A more scientifically accurate term would be "Specific Pathogen Free" (SPF) buffalo. A portion of the success was attributable to the use of dairy cows as foster parents with the five-stage quarantine process proving highly effective in maintaining the "disease-free" status of both the calves and the foster cows. Approximately 460 disease free calves were produced during the life time of the project which ended in 2006. The offspring from these original translocated buffalo continue to reproduce at other locations, including National Parks and on private wildlife ranches. These animals, particularly on private ranches were supplement with animals from European zoos (east African/Ugandan genotypes) and more lately from Namibia.

Breeding of rare species and "stud game: animals

The growth in the rare species and "stud" game breeding industries, have caused a steep and sudden increase in the buffalo numbers and value in South Africa. This point is discussed in more depth below.

2. The current situation

In 2005 JG du Toit, citing Winterbach 1998, provided the following table of the buffalo population in southern Africa[1].

Today, the South African Parks Board (SANParks) boast 35000 buffalo in the KNP, 370 in Addo Elephant Park, 250 in the Mountain Zebra Park with a total in all parks of less than 36 000[10]. Except for the 370 in Addo, most these animals are all "diseased" with either FMD, Corridor Disease, BTb and or brucellosis.

Ownership embodies the "if it pays it stays" idiom used frequently by many game ranchers and some conservators especially hunters in their arguments to preserve their sport. Game ranchers are prepared to invest in their animals now that they owned them. They protected them from poaching, see to preserving their disease status as these are now their valuable assets.

It is not surprising then that the most striking growth in numbers since 1991 has been in the "disease-free" buffalo in South Africa. Reuben Saayman[9], Chairperson of Wildlife Ranching South Africa's (WRSA's), Buffalo Advice Committee estimates there to be at least 100 000 on private game ranches or reserves(more than double the number estimated 16 years ago (1998).

Doktari, (Dr Kevin Robertson) estimated in 1997 that there were 75 000 in Zimbabwe of which 900 or 1,5% were hunted annually[7].

3. The challenges

Challenges to the continued growth of this conservation business are:

The Department of Agriculture, Forestry and Fisheries' (DAFF) veterinary Services' fragmented disease control policies and their lack of capacity

South African Veterinary Services is challenged by 2 main factors, viz.

a. Lack of capacity to attend to their 2 main objectives, i. disease control and ii. community services.

b. The concept of dual competencies between the National- and Provincial Veterinary Services which does not facilitate co-operation between the 2 levels.

As a result full attention and finances are not always directed towards the control of FMD. The latter was addressed and confirmed by the OIE in their recent visits and evaluations to South Africa[11]. As vaccination of game species including African buffalo is neither scientifically supported nor, more importantly practical in most game parks and on most game ranches, WRSA considers FMD to be a major threat to the game ranching industry's future.

Similarly, the lack of capacity, in particular the availability of veterinarians or animal health technicians to attend to test bleeding, to safe transport of blood samples to the laboratories and to attend to the actual transport of animals tested negative greatly hampers the movement and thus the business of buffalo ranching. Years of negotiations have to date yielded very limited progress with DAFF.

Old, outdated environmental legislation

Old, outdated environmental legislation, administered by the Department of Environmental Affairs (DEA), which was enacted to regulate mainly Municipal-, Provincial-, and National Parks as well as endangered species prior to the establishment of the wildlife ranching industry is not conducive the business of game ranching. There are numerous Acts involved and, as with the Veterinary Services, constrains include the 9-plus-1 constitutional concept where the provinces do not necessarily and rarely follow the National Department's lead. All this additional and unnecessary administration adds to the time, the administrative load and the costs needed to move animals to the obvious great frustration of game ranchers.

ISEASE ARRIERS	DISEASE-FREE	TOTAL
7 690	511	48 201
9 077	2 446	31 523
9 367	0	29 367
690	150	2840
08 824	**3 107**	**111 931**
7,2%	**2,8%**	**100%**

Opposition to "intensive" breeding

There is some vehement opposition from some conservationists (preservationists?) and a local hunting group, viz. SA Hunters and Game Conservation Association, to the direction the Wildlife Ranching Industry has embarked as they perceive that this is making the cost of consumptive hunting beyond their means. They also have serious concerns with what they consider the negative conservation implications of the so called "intensive breeding" practices of some ranchers who keep valuable rare species and colour morph animals in camps as small as 10ha. A further "concern" raised is that the game ranching industry is a financial "bubble or a "pyramid scheme". Loudly voicing these views is not conducive to attracting further investment in the game ranching industry and WRSA has to vigorously counter these ill-informed views.

Sales, on auction, of buffalo over the past 10 years have increased 7 fold to 358 individuals in 2013 for a total value that latter year of R360m. To put a "consumptive" perspective on this, the income from hunting in 2011 was 47,5% of the total income for buffalo for the year (52, 5% of the total thus at auctions for live breeding animals).

The record price ever paid for a buffalo bull is R40m paid for a bull called Mystery. He was purchased by Johan Rupert of Rembrandt and Cartier for their property near Graaf Reinet in the Karoo. He is the bull with the longest horns (SCI measurement of 53 3/8 inches) ever offered on auction. In historical terms, he is only the 18th "biggest" ever recorded. Only 2 of the top 17 buffalo on the SCI have been recorded since 2000 and only 3 since 1975 (40 years) illustrating the decline in horn dimensions, probably due to hunting over time (inadvertent genetic selection against the biggest horns).

4. The future

Top breeders are now being recognized as "stud" breeders. These are the most "attractive" animals with respect to various characteristics including amongst various other characteristics: horn length, body size and conformation, typical masculinity and reproductive efficiency. These are also the most sought-after animals and thus are those that attract the best prices. WRSA is in the process of developing, with top local and international geneticists a "breeding" policy for its game rancher members to ensure that the industry limits any negative aspects such as inbreeding, a reduction of genetic diversity and any deleterious genes, e.g. albinism of the current practices. Being "disease free", these animals can be used for reintroductions into areas where buffalo have been extinct for decades. It is foreseen further that other modern technologies such as diagnostic techniques, "stud" breeding software, the treatment of diseases such as corridor disease, vaccination against contagious abortion and a move from regionally based to commodity based trade policies by the member states of OIE will all add further impetus to this industry's remarkable growth and its contribution to the South African economy and conservation of the species.

a. *Managing Director, Afrivet Business Management. President, Wildlife Ranching South Africa (WRSA). Owner, Dabchick Wildlife Reserve, Rankin's Pass, Waterberg District, Limpopo Province, South Africa.*

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ECOLOGY

Home on the Range: Factors Explaining Partial Migration of African Buffalo in a Tropical Environment

Naidoo, R., P. Du Preez, G. Stuart-Hill, M. Jago, and M. Wegmann.

PLoS ONE (2012) 7:e36527.

Partial migration (when only some individuals in a population undertake seasonal migrations) is common in many species and geographical contexts. Despite the development of modern statistical methods for analyzing partial migration, there have been no studies on what influences partial migration in tropical environments. We present research on factors affecting partial migration in African buffalo (*Syncerus caffer*) in northeastern Namibia. Our dataset is derived from 32 satellite tracking collars, spans 4 years and contains over 35,000 locations. We used remotely sensed data to quantify various factors that buffalo experience in the dry season when making decisions on whether and how far to migrate, including potential man-made and natural barriers, as well as spatial and temporal heterogeneity in environmental conditions. Using an information-theoretic, non-linear regression approach, our analyses showed that buffalo in this area can be divided into 4 migratory classes: migrants, non-migrants, dispersers, and a new class that we call ‘‘expanders’’. Multimodel inference from least-squares regressions of wet season movements showed that environmental conditions (rainfall, fires, woodland cover, vegetation biomass), distance to the nearest barrier (river, fence, cultivated area) and social factors (age, size of herd at capture) were all important in explaining variation in migratory behaviour. The relative contributions of these variables to partial migration have not previously been assessed for ungulates in the tropics. Understanding the factors driving migratory decisions of wildlife will lead to better-informed conservation and land-use decisions in this area.

Habitat Selection by African Buffalo (*Syncerus caffer*) in Response to Landscape-Level Fluctuations in Water Availability on Two Temporal Scales

Bennitt, E., M. C. Bonyongo, and S. Harris.

PLoS ONE (2014) 9:e101346.

Seasonal fluctuations in water availability cause predictable changes in the profitability of habitats in tropical ecosystems, and animals evolve adaptive behavioural and spatial responses to these fluctuations. However, stochastic changes in the distribution and abundance of surface water between years can alter resource availability at a landscape scale, causing shifts in animal behaviour. In the Okavango Delta, Botswana, a flood-pulsed ecosystem, the volume of water entering the system doubled between 2008 and 2009, creating a sudden change in the landscape. We used African buffalo (*Syncerus caffer*) to test the hypotheses that seasonal habitat selection would be related to water availability, that increased floodwater levels would decrease forage abundance and affect habitat selection, and that this would decrease buffalo resting time, reduce reproductive success and decrease body condition. Buffalo selected contrasting seasonal habitats, using habitats far from permanent water during the rainy season and seasonally-flooded habitats close to permanent water during the early and late flood seasons. The 2009 water increase reduced forage availability in seasonally-flooded habitats, removing a resource buffer used by the buffalo during the late flood season, when resources were most limited. In response, buffalo used drier habitats in 2009, although there was no significant change in the time spent moving or resting, or daily distance moved. While their reproductive success decreased in 2009, body condition increased. A protracted period of high water levels could prove detrimental to herbivores, especially to smaller-bodied species that require high quality forage. Stochastic annual fluctuations in water levels, predicted to increase as a result of anthropogenically-induced climate change, are likely to have substantial impacts on the functioning of water-driven tropical ecosystems, affecting environmental conditions within protected areas. Buffer zones around critical seasonal resources are essential to allow animals to engage in compensatory behavioural and spatial mechanisms in response to changing environmental conditions.

Potential effects of prescribed savannah burning on the diet selection of forest buffalo (*Syncerus caffer nanus*) in Lopé National Park, Gabon

Hoek, Y., I. Lustenhouwer, K. J. Jeffery, and P. Hooft.

African Journal of Ecology (2012) 51:94–101.

Seasonality and management are factors that may affect the diet selection of the forest buffalo (*Syncerus caffer nanus*). Fire is considered a major driving force in savannah systems and prescribed burning is a commonly applied conservation tool in protected areas such as Lope´ National Park, Gabon. Prescribed annual fires contribute to the maintenance of open areas and provide high-quality forage for forest buffalo, a major herbivore in the park. We used microhistological faecal analysis to determine the diet selection of forest buffalo and measured the extent of variation between a dry season, preburn and a wet season, postburn sampling period. The buffalo diet comprised mainly of monocotyledons, primarily grasses (Poaceae) and sedges (Cyperaceae). Intake of open-area-associated plant species was higher in the wet season, postburn treatment sampling period (97%) than the dry season, preburn sampling period (87%), which corresponded conversely to a reduction in forest-associated Marantaceae plants (10% versus 1%). High proportions of grasses and sedges in the diet signify the importance of open areas for forest buffalo. Controlled burning as tool for maintenance of open areas may play a key role in the meta-population management of the forest buffalo.

Spatial and temporal changes in group dynamics and range use enable anti-predator responses in African buffalo

Tambling, C. J., D. J. Druce, M. W. Hayward, J. G. Castley, J. Adendorff, and G. I. H. Kerley.

Ecology (2012) **93**:1297-1304.

The reintroduction of large predators provides a framework to investigate responses by prey species to predators. Considerable research has been directed at the impact that reintroduced wolves (*Canis lupus*) have on cervids, and to a lesser degree, bovids, in northern temperate regions. Generally, these impacts alter feeding, activity, and ranging behavior, or combinations of these. However, there are few studies on the response of African bovids to reintroduced predators, and thus, there is limited data to compare responses by tropical and temperate ungulates to predator reintroductions. Using the reintroduction of lion (*Panthera leo*) into the Addo Elephant National Park (AENP) Main Camp Section, South Africa, we show that Cape buffalo (*Syncerus caffer*) responses differ from northern temperate ungulates. Following lion reintroduction, buffalo herds amalgamated into larger, more defendable units; this corresponded with an increase in the survival of juvenile buffalo. Current habitat preference of buffalo breeding herds is for open habitats, especially during the night and morning, when lion are active. The increase in group size and habitat preference countered initial high levels of predation on juvenile buffalo, resulting in a return in the proportion of juveniles in breeding herds to pre-lion levels. Our results show that buffalo responses to reintroduced large predators in southern Africa differ to those of northern temperate bovids or cervids in the face of wolf predation. We predict that the nature of the prey response to predator reintroduction is likely to reflect the trade-off between the predator selection and hunting strategy of predators against the life history and foraging strategies of each prey species.

Spatiotemporal dynamics of forage and water resources shape space use of West African savanna buffaloes

Cornélis, D., S. Benhamou, G. Janeau, N. Morellet, M. Ouedraogo, and M.-N. de Visscher.

Journal of mammalogy (2011) 92:1287-1297.

We investigated space-use patterns of the West African savanna buffalo (*Syncerus caffer brachyceros*), a littlestudied subspecies occurring at the northern limit of the African buffalo's geographical range. This buffalo generally ranges in small herds (about 45 individuals) and has a low body mass (approximately 400 kg) relative to the Cape buffalo (*S. c. caffer*). We monitored the movements of 7 breeding herds in W Regional Park (Burkina Faso, Benin, Niger) using global positioning system collars and activity data loggers. Habitat selection was analyzed at both large (interseasonal) and small (intraseasonal) scales in a context where resources are segregated spatially at some times of year. Both biotic (primary production and vegetation types) and abiotic

(timing of rainfall and surface water) covariates, and the extent to which neighboring herds shared space, were considered. In the dry season buffalo herds ranged close (within 5.3 6 2.0 km, mean 6 SD) to segments of permanent rivers. At the onset of the monsoon all herds but 1 (which had year-round access to suitable resources) performed a large (35 6 10 km) directional movement in response to a large-scale gradient of primary production. Spatiotemporal dynamics of forage and water resources thus jointly stimulated interseasonal directional movements and shaped large (335 6 167 km2) annual home ranges. Furthermore, the establishment of home ranges in the wet season appears to be conditioned by a threshold (about 10%) in the availability of perennial grasses. Habitat-selection analysis at intraseasonal scale also underlines the key role played by perennial grasses for buffaloes. The spatial arrangements of home ranges of neighboring herds also suggest that interherd behavioral avoidance is a high-level constraint on foraging processes. The ability of the African buffalo to cope with contrasting environmental conditions throughout most sub-Saharan ecosystems highlights the high behavioral plasticity of this species.

HEALTH

Enemies and turncoats: bovine tuberculosis exposes pathogenic potential of Rift Valley fever virus in a common host, African buffalo (*Syncerus caffer*)

Beechler BR, Manore CA, Reininghaus B, O'Neal D, Gorsich EE, Ezenwa VO, et al..

Proc Biol Sci. (2015) Apr 22;282(1805).

The ubiquity and importance of parasite co-infections in populations of free-living animals is beginning to be recognized, but fewstudies have demonstrated differential fitness effects of single infection versus co-infection in free-living populations. We investigated interactions between the emerging bacterial disease bovine tuberculosis (BTB) and the previously existing viral disease Rift Valley fever (RVF) in a competent reservoir host, African buffalo, combining data from a natural outbreak of RVF in captive buffalo at a buffalo breeding facility in 2008 with data collected from a neighbouring free-living herd of African buffalo in Kruger National Park. RVF infection was twice as likely in individual BTBfl buffalo as in BTB2 buffalo, which, according to a mathematical model, may increase RVF outbreak size at the population level. In addition, co-infection was associated with a far higher rate of fetal abortion than other infection states. Immune interactions between BTB and RVF may underlie both of these interactions, since animals with BTB had decreased innate immunity and increased pro-inflammatory immune responses. This study is one of the first to demonstrate how the consequences of emerging infections extend beyond direct effects on host health, potentially altering the dynamics and fitness effects of infectious diseases that had previously existed in the ecosystem on free-ranging wildlife populations.

Relationship between burden of infection in ungulate populations and wildlife/livestock interfaces

Caron A, Miguel E, Gomo C, Makaya P, Pfukenyi D, Hove T, et al.

Epidemiology and Infections. (2013);141(7):1522-35.

In southern African transfrontier conservation areas (TFCAs), people, livestock and wildlife share space and resources in semi-arid landscapes. One consequence of the coexistence of wild and domestic herbivores is the risk of pathogen transmission. This risk threatens local livelihoods relying on animal production, public health in the case of zoonoses, national economies in the context of transboundary animal diseases, and the success of integrated conservation and development initiatives. The level of interaction between sympatric wild and domestic hosts, defi ning different wildlife/livestock interfaces, characterizes opportunities of pathogen transmission between host populations. Exploring the relationship between infection burden and different types of wildlife/domestic interfaces is therefore necessary to manage the sanitary risk in animal populations through control options adapted to these multi-host systems. Here, we assessed the infection burdens of sympatric domestic cattle (*Bos taurus*/*Bos indicus*) and African buffalo (*Syncerus caffer*) at an unfenced interface and compared the infection burdens of cattle populations at different wildlife/livestock interfaces in the Great Limpopo TFCA. Patterns of infection in ungulate populations varied between wild and domestic hosts and between cattle populations at different wildlife/livestock interfaces. Foot-and-mouth disease, Rift Valley fever and theileriosis infections were detected in buffalo and cattle at unfenced interfaces; bovine tuberculosis was only present in buffalo; and brucellosis and lumpy skin disease only in cattle. At unfenced interfaces, cattle populations presented signifi cantly higher Theileria parva and brucellosis prevalence. We hypothesize that cattle populations at wildlife/livestock interfaces face an increased risk of infection compared to those isolated from wildlife, and that the type of interface could infl uence the diversity and quantity of pathogens shared. Additional host behavioural and molecular epidemiological studies need to be conducted to support this hypothesis. If it is confi rmed, the management of wildlife/livestock interfaces will need to be considered through the prism of livestock and public health.

Livestock and buffalo (*Syncerus caffer*) interfaces in Africa: ecology of disease transmission and implications for conservation and development

Kock R, Kock M, de Garine-Wichatitksy M, Chardonnet P, Caron A.

In: Melletti M, Burton J, editors. Ecology, Evolution and Behaviour of Wild Cattle: Implications for Conservation. Cambridge, UK: Cambridge University Press; (2014). p. 431-45.

Wildlife– livestock– human interfaces are widespread and diverse in Africa, often leading to human– animal conflicts (Kock 2005a; de Garine-Wichatitsky et al . 2012, 2013). The origins of land use challenges are complex. They combine the interplay between conservation and development policies, leading to changes that benefit only a few and to the concentration of pastoral or agropastoral communities in the periphery of protected areas or in wild rangeland (Homewood & Thompson 2010), creating animal health challenges (Kock et al . 2009). These marginalised communities, often politically disenfranchised, bear the brunt of the problem and few benefits of the policies, despite having socio-economic models far better than modern ranching, or agriculture using similar land (Catley et al . 2012). Whatever the cause, conflict at the interface can threaten the success of conservation and development objectives (Osofsky et al . 2005). Old dogma on wildlife as a source of disease remains deeply entrenched in the psyche of many people, but mostly those who are peripheral to the actual keeping of livestock, commercially developed and with large investments at risk from disease events. Recently, in Southern Africa the increased rate of reversion to more integrated landscape approaches, such as transfrontier conservation areas (TFCAs), have facilitated wildlife, livestock and people movement, potentially exacerbating issues at these interfaces (Andersson and Cumming 2013). In most other areas of Africa, open systems have been the normal situation and this has had ecological benefits, but also costs in lost livestock export potential. Understanding the relative costs (lost trade) to benefits (ecosystems services) of more open systems is fundamental to future land use policy in Africa. While Southern Africa begins to tear down fences and open up land, in East Africa policies are tending towards enclosing protected areas or excluding wildlife, threatening ecosystem integrity (Kock 2010). Here we focus on the importance of the sanitary issue at buffalo– cattle interfaces. We describe the main diseases thriving in this context, explore the mechanisms of disease transmission in relation to the type of interface and discuss the implication of this sanitary issue for an integrated conservation and development management of these interfaces across Africa in the face of intense agricultural and human development (Wallace & Kock 2012).

Buffalo, Bush Meat, and the Zoonotic Threat of Brucellosis in Botswana

Alexander KA, Blackburn JK, Vandewalle ME, Pesapane R, Baipoledi EK, Elzer PH.

PLoS One. (2012);7(3):e32842.

Background: Brucellosis is a zoonotic disease of global importance infecting humans, domestic animals, and wildlife. Little is known about the epidemiology and persistence of brucellosis in wildlife in Southern Africa, particularly in Botswana.
Methods: Archived wildlife samples from Botswana (1995–2000) were screened with the Rose Bengal Test (RBT) and fluorescence polarization assay (FPA) and included the African buffalo (247), bushbuck (1), eland (5), elephant (25), gemsbok (1), giraffe (9), hartebeest (12), impala (171), kudu (27), red lechwe (10), reedbuck (1), rhino (2), springbok (5), steenbok (2), warthog (24), waterbuck (1), wildebeest (33), honey badger (1), lion (43), and zebra (21). Human case data were extracted from government annual health reports (1974–2006).
Findings: Only buffalo (6%, 95% CI 3.04%–8.96%) and giraffe (11%, 95% CI 0–38.43%) were confirmed seropositive on both tests. Seropositive buffalo were widely distributed across the buffalo range where cattle density was low. Human infections were reported

reported in low numbers with most infections (46%) occurring in children (,14 years old) and no cases were reported among people working in the agricultural sector.
Conclusions: Low seroprevalence of brucellosis in Botswana buffalo in a previous study in 1974 and again in this survey suggests an endemic status of the disease in this species. Buffalo, a preferred source of bush meat, is utilized both legally and illegally in Botswana. Household meat processing practices can provide widespread pathogen exposure risk to family members and the community, identifying an important source of zoonotic pathogen transmission potential. Although brucellosis may be controlled in livestock populations, public health officials need to be alert to the possibility of human infections arising from the use of bush meat. This study illustrates the need for a unified approach in infectious disease research that includes consideration of both domestic and wildlife sources of infection in determining public health risks from zoonotic disease invasions.

Bovine tuberculosis in Buffaloes, Southern Africa

de Garine-Wichatitsky M, Caron A, Gomo A, Foggin C, Dutlow K, Pfukenyi D, et al.

Emerging Infectious Diseases. 2010;16(5):884-5.

Emergence of bovine tuberculosis (TB) in wildlife in southern Africa has implications not only for the conservation of the wildlife species affected (1) but also for the health of humans and livestock living at the wildlife–livestock–human interface (2). Bovine TB in South Africa's Kruger National Park was first found in African buffaloes (*Syncerus caffer*) in 1990 (3) and likely entered the park by cattle-to-buffalo transmission (4). Bovine TB infection has been spreading northward; in 2003, infection was confirmed in a buffalo ≈ 60 km south of the Limpopo River. In 2005, a case was confirmed only 6 km south of the river (D. Keet, unpub. data). In 2008, we isolated Mycobacterium bovis from African buffaloes in Zimbabwe.

Transboundary Conservation Areas, African Buffalo Movements and Animal Diseases

Caron A, Cornelis D, Foggin C, Hofmeyr M, de Garine-Wichatitksy M.

Emerging Infectious Diseases. Resubmitted after revision.

We report on the long-distance movements of sub-adult female buffalo within a Transfrontier Conservation Area in Africa. These observations confirm that bovine tuberculosis and other diseases can spread between buffalo populations across national parks, community land and countries, posing a risk for animal and public health surrounding wildlife areas.

GENETICS

Genetic structure of fragmented southern populations of African Cape buffalo (*Syncerus caffer caffer*)

Smitz, N., D. Cornélis, P. Chardonnet, A. Caron, M. de Garine-Wichatitsky, F. Jori, A. Mouton, A. Latinne, L.-M. Pigneur, M. Melletti, K. L. Kanapeckas, J. Marescaux, C. Lopes Pereira, and J. Michaux.

BMC Evolutionary Biology (2014) **14**:203.

Background: African wildlife experienced a reduction in population size and geographical distribution over the last millennium, particularly since the 19th century as a result of human demographic expansion, wildlife overexploitation, habitat degradation and cattle-borne diseases. In many areas, ungulate populations are now largely confined within a network of loosely connected protected areas. These metapopulations face gene flow restriction and run the risk of genetic diversity erosion. In this context, we assessed the “genetic health” of free ranging southern African Cape buffalo populations (*S.c. caffer*) and investigated the origins of their current genetic structure. The analyses were based on 264 samples from 6 southern African countries that were genotyped for 14 autosomal and 3 Y-chromosomal microsatellites. Results: The analyses differentiated three significant genetic clusters, hereafter referred to as Northern (N), Central (C) and Southern (S) clusters. The results suggest that splitting of the N and

C clusters occurred around 6000 to 8400 years ago. Both N and C clusters displayed high genetic diversity (mean allelic richness (Ar) of 7.217, average genetic diversity over loci of 0.594, mean private alleles (Pa) of 11), low differentiation, and an absence of an inbreeding depression signal (mean FIS = 0.037). The third (S) cluster, a tiny population enclosed within a small isolated protected area, likely originated from a more recent isolation and experienced genetic drift (FIS = 0.062, mean Ar = 6.160, Pa = 2). This study also highlighted the impact of translocations between clusters on the genetic structure of several African buffalo populations. Lower differentiation estimates were observed between C and N sampling localities that experienced translocation over the last century.
Conclusions: We showed that the current genetic structure of southern African Cape buffalo populations results from both ancient and recent processes. The splitting time of N and C clusters suggests that the current pattern results from human-induced factors and/or from the aridification process that occurred during the Holocene period. The more recent S cluster genetic drift probably results of processes that occurred over the last centuries (habitat fragmentation, diseases). Management practices of African buffalo populations should consider the micro-evolutionary changes highlighted in the present study.

Cape buffalo mitogenomics reveals a Holocene shift in the African human–megafauna dynamics

Heller, R., A. Brüniche-Olsen, And H. R. Siegismund.

Molecular Ecology (2012) **21**:3947-3959.

Africa is unique among the continents in having maintained an extraordinarily diverse and prolific megafauna spanning the Pleistocene–Holocene epochs. Little is known about the historical dynamics of this community and even less about the reasons for its unique persistence to modern times. We sequenced complete mitochondrial genomes from 43 Cape buffalo (*Syncerus caffer caffer*) to infer the demographic history of this large mammal. A combination of Bayesian skyline plots, simulations and Approximate Bayesian Computation (ABC) were used to distinguish population size dynamics from the confounding effect of population structure and identify the most probable demographic scenario. Our analyses revealed a late Pleistocene expansion phase concurrent with the human expansion between 80 000 and 10 000 years ago, refuting an adverse ecological effect of Palaeolithic humans on this quarry species, but also showed that the buffalo subsequently declined during the Holocene. The distinct twophased dynamic inferred here suggests that a major ecological transition occurred in the Holocene. The timing of this transition coincides with the onset of drier conditions throughout tropical Africa following the Holocene Optimum (9000–5000 years ago), but also with the explosive growth in human population size associated with the transition from the Palaeolithic to the Neolithic cultural stage. We evaluate each of these possible causal factors and their potential impact on the African megafauna, providing the first systematic assessment of megafauna dynamics on the only continent where large mammals remain abundant.

Pan-African Genetic Structure in the African Buffalo (*Syncerus caffer*): Investigating Intraspecific Divergence

Smitz, N., C. Berthouly, D. Cornelis, R. Heller, W. F. Van Hooft, P. Chardonnet, A. Caron, H. H. T. Prins, B. Jansen van Vuuren, H. H. De Iongh, and J. R. Michaux.

PLoS ONE (2013) 8(2). e56235.

The African buffalo (*Syncerus caffer*) exhibits extreme morphological variability, which has led to controversies about the validity and taxonomic status of the various recognized subspecies. The present study aims to clarify these by inferring the pan-African spatial distribution of genetic diversity, using a comprehensive set of mitochondrial D-loop sequences from across the entire range of the species. All analyses converged on the existence of two distinct lineages, corresponding to a group encompassing West and Central African populations and a group encompassing East and Southern African populations. The former is currently assigned to two to three subspecies (*S. c. nanus*, *S. c. brachyceros*, *S. c. aequinoctialis*) and the latter to a separate subspecies (*S. c. caffer*). Forty-two per cent of the total amount of genetic diversity is explained by the between-lineage component, with one to seventeen female migrants per generation inferred as consistent with the isolation-with-migration model. The two lineages diverged between 145 000 to 449 000 years ago, with strong indications for a population expansion in both lineages, as revealed by coalescent-based analyses, summary statistics and a star-like topology of the haplotype network for the *S. c. caffer* lineage. A Bayesian analysis identified the most probable historical migration routes, with the Cape buffalo undertaking successive colonization events from Eastern toward Southern Africa. Furthermore, our analyses indicate that, in the West-Central African lineage, the forest ecophenotype may be a derived form of the savanna ecophenotype and not vice versa, as has previously been proposed. The African buffalo most likely expanded and diverged in the late to middle Pleistocene from an ancestral population located around the current-day Central African Republic, adapting morphologically to colonize new habitats, hence developing the variety of ecophenotypes observed today.

Influence of habitat fragmentation on the genetic structure of large mammals: evidence for increased structuring of African buffalo (*Syncerus caffer*) within the Serengeti ecosystem

Ernest, E., H. Haanes, S. Bitanyi, R. Fyumagwa, P. Msoffe, G. Bjørnstad, and K. Røed.

Conservation Genetics (2012) 1-11.

Wildlife species exposed to habitat fragmentation are often in need of a conservation effort. The African buffalo (*Syncerus caffer*) is one of the key species in the Serengeti ecosystem as they form a large part of the herbivore biomass, providing ecotourism and valuable trophies. The ecosystem is a part of Tanzanias protected areas and is administrated under different management practices. Among these, we have analysed the genetic structure of buffalo (n = 68) from the Serengeti National Park (SNP), the Ngorongoro conservation area (NCA) and the Maswa game reserve (MGR). Both the sequence variation in a 493 base pair fragment of the mitochondrial D-loop and the allele frequency-distribution in 15 microsatellites suggest genetic structuring of the buffalo populations within the ecosystem. Both the allele frequency-distribution and the amount of genetic variation were high and similar in SNP and MGR, suggesting a high degree of gene flow between these locations. By comparison, the NCA buffaloes had significantly lower genetic variation and were genetically differentiated from SNP and MGR. Approximate Bayesian computation estimates suggest that the observed genetic structure is of a recent origin, indicating that the recent increases in developmental activity in the region may have influenced the genetic structure of the buffalo within the Serengeti ecosystem.

Gene Polymorphisms in African Buffalo Associated with Susceptibility to Bovine Tuberculosis Infection

le Roex, N., A. P. Koets, P. D. van Helden, and E. G. Hoal.

PLoS ONE (2013) **8**:e64494.

Bovine tuberculosis (BTB) is a chronic, highly infectious disease that affects humans, cattle and numerous species of wildlife. In developing countries such as South Africa, the existence of extensive wildlife-human-livestock interfaces poses a significant risk of Mycobacterium bovis transmission between these groups, and has far-reaching ecological, economic and public health impacts. The African buffalo (*Syncerus caffer*), acts as a maintenance host for Mycobacterium bovis, and maintains and transmits the disease within the buffalo and to other species. In this study we aimed to investigate genetic susceptibility of buffalo for Mycobacterium bovis infection. Samples from 868 African buffalo of the Cape buffalo subspecies were used in this study. SNPs (n = 69), with predicted functional consequences in genes related to the immune system, were genotyped in this buffalo population by competitive allele-specific SNP genotyping. Case-control association testing and statistical analyses identified three SNPs associated with BTB status in buffalo. These SNPs, SNP41, SNP137 and SNP144, are located in the SLC7A13, DMBT1 and IL1a genes, respectively. SNP137 remained significantly associated after permutation testing. The three genetic polymorphisms identified are located in promising candidate genes for further exploration into genetic susceptibility to BTB in buffalo and other bovids, such as the domestic cow. These polymorphisms/genes may also hold potential for marker-assisted breeding programmes, with the aim of breeding more BTB-resistant animals and herds within both the national parks and the private sector.

CAPE BUFFALOES

A. *Uganda (©C. Spinage)*
B. *Zimbabwe (©D. Cornélis)*
C. *South Africa (©A. Fusari)*

CAPE BUFFALOES

D. *Zimbabwe (©A. Caron)*
E. *Mozambique (©T. Prin)*
F. *Zambezi delta, Mozambique (©P. Chardonnet)*

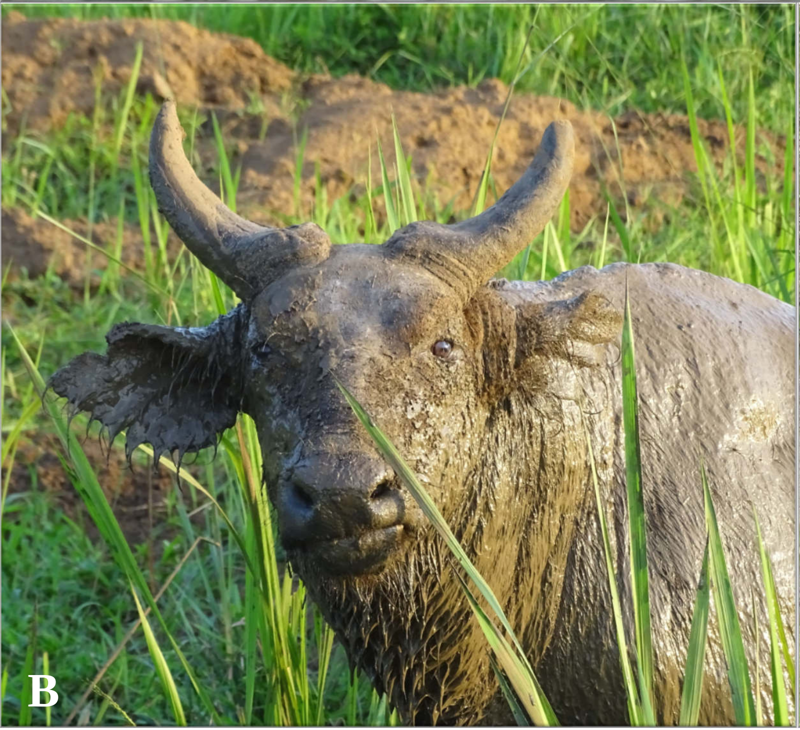

D


E


F

FOREST BUFFALOES

A. *Congo (©C. Morio)*
B. *Congo (©C. Morio)*
C. *Congo (©C. Morio)*



FOREST BUFFALOES

D. *Gabon* (©M. Bourgarel)
E. *Gabon* (©P. Chardonnet)

D

E

WEST AFRICAN SAVANNA BUFFALOES

A. *Niger (©D. Cornélis)*

WEST AFRICAN SAVANNA BUFFALOES

B. *Niger (©D. Cornélis)*
C. *Niger (©P. Chardonnet)*

B

C

CENTRAL AFRICAN SAVANNA BUFFALOES

A. *Chad (©D. Cornélis)*
B. *Chad (©D. Cornélis)*

HANDLING BUFFALOES

A. *Mozambique (©IGF Foundation)*
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C. *Niger (©D. Cornélis)*

BIRDS & BUFFALOES

A. *Cattle egret & Cape buffalo, Uganda (©D. Cornélis)*
B. *Hamerkop & forest buffaloes, Congo (©C. Morio)*
C. *Yellow-billed oxpecker & forest buffaloes, Gabon (©P. Chardonnet)*