16 · *Conserving Africa's Mega-Diversity in the Anthropocene: The Hluhluwe-iMfolozi Park Story*

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16.1 Introduction

The Hluhluwe-iMfolozi Park (HiP) is relatively small in its area in comparison with well-known protected areas elsewhere in Africa: a mere 950 km^2, compared with the 14,763 km^2 of Serengeti National Park and 19,500 km^2 of Kruger National Park. Moreover, its boundaries are completely fenced, meaning that animals cannot migrate or readily disperse beyond them. Yet within its limits it contains a full representation of the megafauna typical of the African savanna biome: African elephant, black and white rhino, hippo, giraffe, and all five large mammalian carnivores. Alongside them is a diversity of less-large grazing and browsing ungulates (16 species) and numerous smaller organisms. Vegetation formations contained within HiP are exceptionally diverse, ranging from semi-arid thorn savanna in lowlands in the south through mesic savanna and dense thickets in the wetter north and a grassland–forest mosaic on the highest hills. Contributing to this is a rainfall gradient from under 600 mm to almost 1000 mm over a distance of only 35 km, along with an underlying diversity in geological substrates and soils. Traversing the region are two major rivers, one perennial until recently, the other always seasonal in its flow. These features of HiP provided an exceptional natural laboratory for investigating processes such as the impacts of mega-grazers on grasslands, biome transitions, competition between woody plants and

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grasses, the role of fire, impacts of predators and pathogens, and alien plant invasions. The scientific understanding gained has guided 'process-based management' interventions such as predator restoration, re-introduction of elephants, population management through dispersal sinks and live capture, applications of fire, and eradication of invasive plants. The park may be viewed as a successful example of how Africa's mega-diversity of large mammals can be conserved within a remnant of formerly vaster ecosystems, but how sustainable will these conservation efforts be?

In this final overview, we highlight research findings from HiP that have made major contributions to scientific understanding globally, and outline their implications for conservation practice. We conclude by looking forward from past human impacts towards a prognosis of the alternative scenarios that might eventuate in the context of the human-dominated epoch that has become labelled the Anthropocene (Crutzen and Stoermer, 2000; Corlett, 2015; Ellis, 2015). We explore how this relates to the different conservation philosophies that have shaped HiP's past and present and how they may continue to shape its future. Central in these philosophies is the question of what exactly we are trying to conserve. What traction does the idea of a 'Zululand wilderness' (Player, 1997; McCracken, 2008) still have during the 'Anthropocene' epoch (Crutzen and Stoermer, 2000), when humans and their activities both replace and modify climate as the overriding influence on ecological conditions and processes (Corlett, 2015; Ellis, 2015)?

16.2 Megaherbivore Ecology

Foundations for the megaherbivore concept emerged from a pioneering study of white rhinos conducted within HiP (Owen-Smith, 1973; Chapter 5). This led to the recognition of common features shared by rhinos with elephants, hippos, and other large herbivores attaining weights exceeding 1000 kg. These include invulnerability to predation once adult, inter-birth intervals longer than 1 year, dominance of community biomass, and capacity to transform vegetation structure (Owen-Smith, 1988, 2013). Although megaherbivores were once more common worldwide (Owen-Smith, 1987), HiP represents perhaps the only protected area in the world where an intact megaherbivore community still exists (Chapters 4 and 5). There are no other areas in Africa where black and white rhino, hippo, elephant, and giraffe co-occur at functionally relevant densities and have done so for several decades. A particularly unique feature of HiP is that it is only here that the full impacts of white rhinos on grassland structure and composition and related processes can be observed – in most other places their numbers are still recovering after re-introductions. This is relevant because the white rhino is the only extant mega-grazer with widespread impacts on grasslands, because those of hippos are restricted to the margins of rivers and lakes (Lock, 1972). Studies in HiP have shown that the white rhino plays a key, and diverse, role in the functioning of HiP's savannas (see Chapters 5, 6, and 10), increasing grassland heterogeneity, creating habitat for a suite of species from diverse taxa, restricting the spread of fires and the loss of nitrogenous material associated with burning, and potentially limiting the spread of woody plants.

The transforming impact that megaherbivores can have, not only on vegetation but also on a variety of ecosystem processes, has become widely recognized (Owen-Smith, 2013). The megaherbivore concept is increasingly being applied elsewhere, beyond the extant savannas of HiP where it originated (Mahli *et al*., 2016). Assessments of the role of extinct Pleistocene megaherbivores in ecosystem functioning are currently booming (e.g. Barnosky *et al*., 2015; Doughty *et al*., 2015a,b; Bakker *et al*., 2016; Mahli *et al*., 2016; Smith *et al*., 2016). These studies have linked the extinction of megaherbivores towards the end of the last ice age to continent-scale shifts in vegetation structure and composition (Zimov *et al*., 1995; Gill, 2014; Doughty *et al*., 2015a), large-scale changes in nutrient availability and distribution patterns (Doughty *et al*., 2013; Doughty *et al*., 2015b), and global-scale effects on biogeochemical cycling (Smith *et al*., 2016) and climate warming (Doughty *et al*., 2010; Brault *et al*., 2013). So how do all these findings fit with the work on megaherbivore ecology from HiP? Although the white rhino has received considerable research attention in HiP, much less is known about the ecological roles of the other megaherbivore species. While elephants have been linked to significant ecosystem impacts elsewhere (Kerley *et al*., 2008), their impact in HiP remains largely unclear, although their potential impact on vegetation is a growing concern in HiP (Chapter 14). Our understanding of the ecosystem impacts of other mega-browsers, such as giraffe and black rhino, remains poor, not only within HiP. Hence there are particularly large knowledge gaps to fill regarding the ecosystem-level impacts of several of the extant megaherbivore species, and of the megaherbivore community as whole.

Unfortunately, we may not have that much time left to learn about the role of extant megaherbivores. Across Africa, escalating poaching of rhinos and elephants is threatening to reverse the gains in conservation of these endangered species that have been achieved over past decades. Poaching of elephants is not an issue in HiP at the time of writing, but losses of both white and black rhinos have been on the rise, despite the patrolling and other steps that have been taken to restrict incursions of poachers (Chapter 11). A particular threat is that poaching limits legal sales of live rhinos via game auctions, which generate essential revenue for conservation as well as distributing the species more widely. In Kruger National Park, poaching levels are now so high that management removals, through live auction sales, have been suspended (Ferreira *et al.*, 2012). Furthermore, interest in rhino purchases by potential buyers is declining due to the huge costs involved in effectively protecting them. The fate of HiP's rhinos remains uncertain at the time of writing this book.

16.3 Redefining Biomes

Savannas have always been a contentious biome-type and the debate around how to define mixed tree–grass ecosystems has intensified in recent decades (Ratnam *et al.*, 2011). Climatic variables alone do not delineate the structure and species composition of these ecosystems very well because fire and herbivory may promote alternative vegetation states, from open grassland to closed woodland, under similar environmental conditions (Chapters 3 and 10; Staver *et al.*, 2011; Hoffmann *et al.*, 2012). Globally, similar vegetation physiognomies are often classified as different biomes (mesic savanna vs dry forest), playing havoc with global maps of savanna extent and complicating decisions around how they should be managed. Again, this global issue plays out on the small HiP stage; vegetation maps have been interpreted and reinterpreted by different scientists/managers with different agendas.

Elements of grassland, savanna, forest, and thicket are all found within the ~950 km^2 boundaries of HiP and the ratios of these different vegetation formations have clearly changed over time (Chapter 3). Many people would object to the notion that the park contains four biomes. They would argue that this undermines the concept of a biome as a global-scale vegetation unit. Chapter 8 in this book presents a different view, where biomes are seen as ecological constructs in which different processes dominate, and both ecological and abiotic controls prevent species from passing easily from one formation to the other even over the space of a few metres (cf. Crisp *et al.*, 2009). Research from HiP and elsewhere brings into question the definition of biomes as global-scale, climatically determined vegetation units. Instead, it suggests that biomes are functionally divergent units, many of which are maintained through feedbacks between vegetation and consumers (fire and/or herbivory) against the backdrop of climatic and edaphic factors (Charles-Dominique *et al*., 2015; Moncrieff *et al*., 2016).

Why is this debate over the biome concept important? The ease with which remotely sensed images can be produced makes it tempting to use vegetation structure alone to map vegetation units. Findings from HiP and elsewhere suggest that identifying tree cover/biomass thresholds to distinguish forests, savannas, and thickets will not work. Instead, looking at the functional attributes of the dominant species in these environments can produce maps of greater accuracy and meaning. From the perspective of HiP, this novel approach has certainly cleared up the confusion over the difference between encroached savanna grasslands dominated by savanna shrubs vs functionally distinct thickets (Chapters 2 and 8). It sets out clear guidelines for management (Chapter 10), and gives a functional basis for determining appropriate levels of change (Gillson, 2015).

This is also highly relevant at a global scale. Many of the world's grassy biomes are currently threatened by global re- and afforestation programmes, such as REDD+ and more recently the Bonn Challenge and AFR100 (www.wri.org; Veldman *et al*., 2015a,b,c; Bond, 2016a). These programmes use global mapping exercises that model forest potential using climatic and soil data while ignoring fire and herbivory as intrinsic drivers of tree cover (Laestadius *et al*., 2011). As a result, many of the world's savannas and grasslands are mapped as degraded land with forestation potential (see the Atlas of Forest Landscape Restoration Opportunities: www.wri.org/applications/maps/flr-atlas/#). For example, according to these maps that seem to be made to guide policy makers, almost the complete extent of HiP is classified as a degraded landscape with forest restoration opportunities (something which would decimate the biodiversity and tourism opportunities of the reserve if it were ever implemented). Global re- and afforestation programmes thus make distinctions between degraded forests and savannas highly politicized and the definition and classification of these biomes highly debated: the same patch of land can be seen as a pristine habitat or something valueless that needs to be rehabilitated, depending on the definitions used and the ecological perspective of the viewer (see the debate between De Wit *et al*., 2016 and Bond, 2016a,b).

Finally, these novel approaches to understanding and defining vegetation formations in savannas provide an alternative framework for looking at any ecosystem. Freeing the biome concept from the constraints of being associated with regional climates requires that these ideas be re-examined in temperate and boreal ecosystems as well – potentially furthering our understanding there (see Kuijper *et al*., 2015). At the basis of this novel thinking is the research in HiP, highlighted in Chapters 7 and 8. This emphasizes the importance of demographic bottlenecks for savanna trees at different life-history stages as a conceptual model that is both scientifically valid and easy to translate into clear management options. Key to this model is the integration of resource constraints on growth and factors that determine the disturbance regime (fire and herbivory) within which tree species complete their life histories. This allows these ideas to be generalized to systems with different resource environments and in the context of changing fire and herbivory regimes globally.

16.4 Dynamics and Population Management of Large Herbivores within Enclosed Areas

A contentious issue in wildlife management has been whether large herbivore populations within small fenced parks need to be culled to prevent overgrazing and resultant population crashes (Jewell *et al*., 1981). This was not an issue in the early days of HiP, because back then 'game' numbers were still recovering from attempts to eradicate all hosts of tsetse flies. However, during the 1950s, following the arrival of the first park ecologist, concerns were raised about vegetation changes and the poor body condition of certain ungulates within the Hluhluwe Game Reserve, which had remained mostly protected from the shooting campaigns (Chapter 4). Given the lack of large predators at the time, culling was introduced to control the more abundant herbivores, except for the two rhino species. Animal removals expanded to such extremes that when the especially severe El Nino-related drought of 1982/3 occurred, hardly any animals died of malnutrition within HiP (Walker *et al*., 1987). This led to the recognition that agricultural concepts of carrying capacity were inappropriate for a protected area (Caughley, 1983) and animal removals became restricted to live sales of animals for restocking other parks or commercial wildlife ranches. The low numbers of animals removed in this way meant that herbivore populations were allowed to grow and attain their own equilibrium densities within the fenced park (Chapter 4). As a result, most large herbivore species did indeed increase in numbers from the mid-1980s onwards.

The exceptions included several of the smaller antelope species, which declined to levels threatening their imminent local extinction (Chapter 4). Over time, the herbivore community in the park has changed drastically in its species composition. Bushbuck, both reedbuck species, waterbuck and blue and grey duiker were abundant at the time of the early twentieth-century shooting campaigns, but are now reaching the verge of local extinction. Eland, formerly abundant in the region, are no longer present, an attempt at re-introduction having failed. In contrast, impala, nyala, and giraffe, not historically recorded within the boundaries of HiP, have thrived.

Shifting ideas about population control went hand in hand with the restoration of large predators, starting with lions in 1965 and followed by cheetahs in 1966 and wild dogs in 1980. Initially, the presence of lions had little impact on the abundance of their prey species, and it became apparent that the lion population was suffering from the effects of inbreeding due to the small founding nucleus. To restore genetic diversity, further lions were introduced between 1999 and 2001, and after initial ups and downs lion numbers have grown to over 100 individuals at the time of writing (Chapter 12). Recent census estimates indicate sharp downturns in the abundance of the ungulate species forming the primary prey of lions, in particular wildebeest and zebra, but notably also impala and nyala (Chapter 4). It may be that wild dogs and cheetahs are also contributing to the declining abundance of the latter two herbivore species, and perhaps also to the near demise of some of the smaller antelope species. Hence the leading issue, as yet unresolved, is whether predator and prey populations can attain joint quasi-equilibrium levels within a protected area the size of HiP, or whether the persistent oscillations projected by simple models of predator–prey systems will be generated. Time will tell. Nevertheless, at no stage in the history of HiP has any species exhibited a persistent 'carrying capacity' and population fluctuations of all ungulate species during the last century have been largely a consequence of management interventions rather than environmental variables (Chapter 4).

HiP has brought about important advances in terms of the population management of megaherbivores. Park managers have applied sustainable live removal programmes for rhinos, while maintaining the functional impacts of these ecosystem engineers (Chapter 11). For white rhinos, the innovative strategy adopted was to simulate natural dispersal processes by restricting animal removals to designated dispersal sink zones (Chapter 11). For black rhinos, the aim has been to re-establish a wider metapopulation of the species by targeted translocations of animals to other areas. In the case of elephants, the management dilemma is how to restrict the vegetation impacts of such a wide-ranging species within a small protected area. The size of HiP is equivalent to just one elephant home range, meaning that all parts are vulnerable to their vegetation impacts. Live removals of elephants are currently not a feasible option because most protected areas in southern Africa now contain dense elephant populations. While lethal control of smaller ungulates has been undertaken several times in the history of HiP, this is anathema to most conservationists for highly sentient species such as the elephant. So, a leading question remains, if poaching threats are resolved, how do we deal with (over)abundant populations of both elephants and white rhinos in small protected areas in the future? Large-scale contraception of elephants is currently being tested in HiP and the effectiveness of this intervention is awaited.

16.5 Humans and the 'Zululand Wilderness'

The role and place of humans in 'nature' or 'wild, natural' areas has been a popular subject of philosophical debates. One such philosophy, the wilderness philosophy, has been very influential in HiP's conservation history, reflected by the concept of the 'Zululand Wilderness' (Player, 1997; McCracken, 2008). In fact, HiP was the first park in Africa to designate a wilderness area in 1957. Up to this day, there are no roads or other infrastructure in this area, which covers about one-third of HiP, and human activities are restricted to wilderness trails and management interventions that leave minimum evidence in the landscape (Ezemvelo KZN Wildlife, 2011).

However, this book has clearly described how the land enclosed by HiP has been subject to anthropogenic influences for many millennia (Chapter 1). At least as far back as 0.5 MYA, Stone Age hunter-gatherers were using the area for hunting, and their impacts became more significant from ~100,000 years BP through altering the fire regime (Chapter 10). During more recent millennia, iron smelting and livestock herding activities altered vegetation structure and composition and soil nutrient patterns across large parts of the landscape (Chapters 1 and 6; Feely, 1980; Hall, 1984). The area that we now know as HiP was in fact fairly densely settled by Late Iron Age people during the eighteenth and nineteenth centuries (Penner, 1970; Feely, 1980; Hall, 1984), but it is clear that up to the early to mid-1800s these people lived alongside abundant wildlife populations (see Chapter 4). Hence, past human occupation of this region largely retained landscapes with high vegetation heterogeneity and biodiversity. Humans have thus played a clear role in shaping the 'Zululand Wilderness' that we now want to conserve.

However, during more recent times, unprecedented human population densities and land-use intensification surrounding HiP are affecting ecosystems inside the park and threatening biodiversity conservation objectives. For example, alien plant invasions, mostly brought in via roads entering the park, have had dramatic effects on riverine vegetation and fire regimes (Chapter 15). Increased livestock densities outside the park have also brought new pathogens affecting wildlife inside, most notably lion, African wild dogs, and buffalo (Chapter 13). Moreover, even the 950 km^2 extent of HiP is far too small to contain the range dynamics of some (e.g. vultures, wild dogs, or elephant) and genetically viable populations of other (e.g. lion) species (Chapters 9, 12, and 14). In the light of all these pressures, conserving ecological processes and ecosystem functioning within relatively small protected areas such as HiP has required, and will continue to require, targeted interventions.

This book highlights how HiP has 'experimented' with a wide range of such management interventions. In the early days spotted hyenas (Potter, 1941) and wild dogs (Vaughan-Kirby, 1916) were poisoned within Hluhluwe GR to restrict their impacts on depressed herbivore populations (Chapter 12), but later the larger herbivores were subjected to culling when perceived overgrazing became a problem within Hluhluwe GR and later in Umfolozi GR (Chapter 4). Culling was curtailed after reassembly of the large predator assemblage (Chapter 12). Later interventions also included more direct examples of 'learning by doing', where HiP's management pioneered the concept of adaptive management. Examples include prescribed burning to reduce woody encroachment (Chapter 10), the white and black rhino offtake programmes (Chapter 11), its science-led bovine tuberculosis programme (Chapter 13), and its massive response to the *Chromolaena* problem (Chapter 15).

Increasingly, conservation management recognizes that spatial and temporal variability is part of the system that needs to be conserved (Chapter 1). In the Kruger National Park, this has resulted in a clear policy of 'thresholds of potential concern (TPCs)' – where variability in various indicators is allowed and interventions are contemplated only when thresholds of change are exceeded. A similar approach is being introduced in HiP, for example in the context of elephant management, with several indicators of concern being listed that might trigger management intervention (Chapter 14). Solid scientific understanding and responsive management are necessary, but not sufficient, for this TPC approach to work: we also need to be able to identify allowable variation and associated thresholds. The fire management chapter (Chapter 10) exemplifies this: the challenge here is not our ecological understanding or our ability to apply fire to different ends. Rather, it is our struggle to determine acceptable landscape change, and to weigh up the positive and negative impacts of interventions on different aspects of ecosystem functioning.

An arguably even larger challenge for relatively small areas such as HiP is managing relations with human communities living outside the park. Today, HiP is not only expected to (1) 'Protect a representative sample of the indigenous ecosystems, communities, ecotones and representative landscapes of the area, their indigenous biodiversity, and the ecological and evolutionary processes that generate and maintain this diversity'. It is also expected to (2) 'safeguard cultural heritage', (3) 'promote awareness of nature', (4) 'contribute to local, regional and national economies', and (5) 'enable research to improve understanding and management' (Ezemvelo KZN Wildlife, 2011). These diverse objectives are a far cry from the original intention, which was to 'prevent total destruction of game' (Chapter 1). This highlights the challenge of conservation in the Anthropocene. Not only is the park more heavily impacted by people and their activities than ever before, but it is also expected to provide more resources, education, and conservation value than before. HiP's conservation agency, Ezemvelo KZN Wildlife, runs a number of community-based conservation programmes to enable neighbouring communities to share in the revenue (through community-owned lodges and community levys), resources (access to thatching grass and seedlings), management decisions (representation on the governing board), and educational opportunities (community trails and visitor centres) that the park offers. Whether these programmes engender a sufficient sense of shared ownership and value among neighbouring communities remains to be seen.

16.6 Looking to the Future

Over a century after the original Hluhluwe and Umfolozi game reserves were proclaimed, and 65 years after management responsibility for the entire protected area was assumed by the conservation agency, the status of the biodiversity contained within HiP appears to represent an outstanding achievement. A large and thriving population of white rhinos has been established, black rhinos are more abundant than in most other places, and elephants plus all large carnivores have been restored. Almost all of the large mammals indigenous to the region are represented, albeit in variable numbers, along with a wide diversity of birds and other taxa. The park continues to attract local and international tourists.

However, key conservation challenges remain and will need resolving: (1) expanding human settlements and associated activities press strongly against the boundaries of the park (along with threats of activities such as mining); (2) water flows and water quality are declining due to increasing pressures on the larger rivers beyond the park boundary; (3) poverty and poor health are a huge problem in neighbouring communities and the park's contribution towards their remediation will increasingly be questioned; (4) the escalation in rhino poaching fuelled by the huge prices paid for their horns; (5) the ecological implications of growing elephant numbers; (6) the spread of woody plants with consequent effects on habitat conditions and game viewing; (7) the consequences of increasing numbers of the large carnivores for predator–prey dynamics; (8) the threatened local extinctions of several of the smaller ungulate species; (9) the persistence of *Chromolaena* and other alien plant invaders; (10) the persistence of bovine tuberculosis in the buffalo population; and (11) the need for ongoing augmentation of large carnivore numbers.

Among all these concerns, climate change seems quite far down the list. HiP is small, which should make it vulnerable to changes in temperature and rainfall. However, the wide range in climate and topography within the park should increase its resilience to projected changes. The potential impact of higher temperatures on the probability of extreme fire events is under investigation (Chapter 10), but more work could be done on plant and animal phenology, and the more insidious effects of elevated CO_2.

A challenge shared by all small fenced reserves is how to maintain ecosystem processes which formerly operated at larger scales than HiP encompasses. The protected area exists as a fenced fortress with wild animals within and domestic ungulates and people outside (Figure 1.6). Despite this, opportunities to extend the park area could be explored. Community-controlled wildlife reserves have been established adjoining the park, albeit small in size (Chapter 14). There is a possibility that HiP could be extended northwards via a corridor through communal land and adjoining private nature reserves to become linked with the iSimangaliso Wetland Park, which includes Mkhuze Game Reserve, on the coastal plain. This would require an underpass beneath a major highway to be constructed and used by animals, as well as dropping fences to connect with protected areas north of HiP.

This book has documented many examples of how HiP's conservation agency and its staff have responded to the challenges of conserving Africa's mega-diversity within a comparatively small area. Often this was done in close collaboration with researchers, and process-related concepts have guided management responses. Nevertheless, further challenges will need to be surmounted if this conservation success is to be maintained further. The experience gained in HiP has wider relevance for protected areas that are becoming contracted in their effective extent elsewhere in Africa. We hope that HiP will continue to be a pioneer in responding to forthcoming conservation challenges in the emerging contexts of the Anthropocene.

16.7 References

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