Synthesis

Conservation management changed greatly over the last four decades (e.g. Western 2003). One such change involves the management of elephants. Priorities shifted from treating elephants as an endangered species (Douglas-Hamilton 1987; Caughley *et al.* 1990) to situations where some regard them as a commercially exploitable species (Leader-Williams *et al.* 2001; Stiles 2004; Bulte *et al.* 2004; Hambler *et al.* 2005). The situation arises when measures such as fencing conservation areas and the provision of artificial water allow elephant numbers to increase (for a review on recent trends in elephant numbers see Blanc *et al.* 2005). Current concerns revolve around local elephant densities exceeding the so-called 'ecological carrying capacities' of protective areas (e.g. Gillson & Lindsay 2003). This prompted one of the central questions amongst conservationists today – what are the consequences of confined elephants for these fenced conservation areas?

The issue at hand is whether conservation management should intervene and prevent elephants from destroying components of biodiversity, and if so, how (e.g. Cumming *et al.* 1997; Whyte 2004). This issue is by no means new, shortly after the cessation of World War II, Eggeling (1947) pointed to the destruction that elephants caused in the rainforests of Uganda. The matter remains unresolved, with wildlife managers continually seeking justification for the control of elephant numbers (e.g. Whyte 2004). Appendix B provides the most comprehensive reference list of peer-reviewed studies dealing with this topic up to December 2004.

The Tembe Elephant Park in Maputaland is another place with a potential 'elephant problem'. The Park is fenced, and apart from elephants, supports a unique sand forest ecotype (Kirkwood & Midgley 1999; Matthews *et al.* 2001). This forest type is high in species diversity and contains many endemic species (van Rensburg *et al*. 1999, 2000; Haddad 2003). Elephants may threaten this diversity and endemicity as well as those of the mixed woodlands in the Park (see Matthews *et al*. 2001; McGeoch *et al*. 2002). My study aimed at addressing these concerns and to give some insight into the concept of 'elephant impact'.

I relied on the comparative approach while studying the influence of elephants at different scales. This approach strengthened my assessment of the impact elephants may have had for some plant variables at different scales. I distinguished between the micro-, meso-, and macro scales and used a meta-analysis to determine differences in local, regional and the overall effect of elephants. For the micro- and meso scales, I studied the effect elephants had for plants and plant communities in the Tembe Elephant Park. The macro scale assessment reflected on how confined elephants responded to space and landscapes, and how such information can be used to formulate alternative management options for elephants. The meta-analysis included response variables for plants, insects, birds and mammals across Africa.

At the micro scale level (Chapter 3), I focussed on the potential consequences tree canopies altered by elephants have for sub-canopy vegetation. The response of such plants depended on vegetation type – in closed woodlands, elephants created gaps in the canopy and this allowed grass species to establish. In these gaps the woody saplings could also reach the upper canopy strata. In the open woodlands, elephants created conditions similar to the areas where no trees were present. Here, species not normally associated with canopies, may be replaced by shade-tolerant species. Therefore, at the local level, elephants increased heterogeneity in the closed woodlands, but homogenised open woodlands.

At the meso scale (Chapter 4), I compared woody plant community variables for sand forests, and the open and closed woodlands inside the Tembe Elephant Park to similar plant communities outside the Park. Species composition for all three of the landscape types differed significantly between the areas inside and outside of the Park. However, tree and shrub densities, abundance-incidence and rank-abundance relationships did not differ when comparing sample sites inside and outside the Park. Elephants may have had little impact at the regional and landscape level. On the other hand, larger scale events such as droughts, fire and seed dispersal may have masked the impact elephants had for these plant community variables.

At the macro scale (Chapter 5), I studied the effect that the fencing of Tembe Elephant Park had on the home ranges and landscape selection of elephants. I used a rainfall gradient to interpret my findings on the variability of home range sizes across southern Africa. The analysis of landscape preference focused on comparing confined elephants living in the fenced off Tembe Elephant Park with the free ranging elephants living in southern Mozambique (those occurring in Maputo Elephant Reserve and along the Futi River). Elephant home ranges in the Park were a third of the size of those of elephants occurring in southern Mozambique, but still falls within the range of sizes predicted by the rainfall gradient implied by studies conducted across southern Africa. Landscape selection patterns, however, differed between the two elephant groups – in southern Mozambique, elephants preferred closed woodlands throughout the study period. In the Tembe Elephant Park, elephants show no clear preference, except for avoiding the Muzi Swamp in the dry season. This is against expectation, as elephants are a water-dependent species, and the swamps contain reed beds and natural surface water. The provisioning of drinking water under these confined conditions may influence the way that elephants use the area – this may have consequences for biodiversity.

The meta-analysis (Chapter 6) focussed on the impact that elephants have on their environment. Here I investigated how the interpretation of published results on elephant impact shaped perceptions. Twenty of the 230 peer-reviewed articles I collated (listed in Appendix B) dominated the literature with more than 50% of the total citations referring to these. The remaining 210 articles shared the remainder, with 70 of these receiving no citations. Sixteen of the dominant 20 studies concluded that elephants had a negative effect on plants. My results showed that studies conducted over shorter periods concluded that elephants affect other species negatively – long-term studies did not support this. However, I acknowledge that site-specific characteristics influence the overall outcomes, as sites with short-term studies were different from those with long-term studies. This holds for both experimental and observational studies. A further caveat is that researchers have chosen different response variables and focal taxa. For instance, studies based on vegetation responses used response variables that showed immediate effects after an elephant fed on a tree, such as damage indices, measurement of structural changes, decrease in abundance and mortality rates. Studies on birds, insects and small mammals tended to focus on community parameters. Intuitively this too makes sense – elephants do not feed on them, so damage indices and mortality rates are unrealistic. Community indices in general are due to their character, more likely to show less of an elephant effect.

To summarise, elephants had a combination of positive, neutral and negative effects on plant variables at the micro- and meso scales in Tembe Elephant Park. It is clear that responses to elephants vary, which motivated the meta-analysis. With this, I was able to show that one should consider a large number of aspects in the design and interpretation of elephant impact studies. These include the methods employed, the response variables used, whether the study design controlled confounding factors and the study duration. Study site characteristics, such as mean annual rainfall, the dominant soil types and aspects of fire and water management may play an additional role. Interpretation should consider other stochastic and deterministic processes, such as those associated with climate change; this leads me to ask what do these meta-results mean for the managers of the elephants in the Tembe Elephant Park?

The results of my thesis were not included in the meta-analysis, as it is only currently been evaluated for publication in peer-reviewed journals. I therefore took the results from the micro- and meso scale chapters for the different landscape types, and re-analysed them using the same meta-analytical techniques as in Chapter 6. I refer to the results as a "park effect" and present the results in Appendix C (Fig. 7.1). In this re-analysis, I did not specifically control for elephant presence as I did in the previous chapters, and used the differences in all the responses variables between inside and outside the Park. The overall effect size was significantly negative (d = -0.24 ± 0.01, $p < 0.05$, 95% CI: -0.43 to -0.05, k = 45). The open woodland dominated this overall effect and was significantly negative (d = -0.39 ± 0.02, $p < 0.05$, 95% CI: -0.66 to -0.11, k = 21). Note that the effect size was not significant in the closed woodland and sand forests, that is, the 95% confidence interval overlapped with zero (for closed woodland: d = -0.17 ± 0.02, $p < 0.05$, 95% CI: -0.44 to 0.10, k = 21; sand forests: d = 0.24 ± 0.14, $p < 0.05$, 95% CI: -0.49 to 0.96, k = 3 respectively). If the conservation goal was to maintain ecological integrity, the Park has a problem that extends beyond elephants (see Chapter 6 and these results; and options for solutions under the next heading). Overall, the sand forests appeared to be intact, and the mixed woodlands seem to be under pressure from not just elephants, but also management policies towards other herbivores, water and fire.

Two closely linked aspects guided me in my conclusion. Firstly, ecological patterns and processes are scale dependant (Lewin 1986; Levin 1992; May 1994) and secondly, elephants do not operate in isolation (e.g. Dublin *et al*. 1990). Other ecological events may either mask or synergistically contribute to the effect elephants have for their environment. At what scale then do we see a signal of impact left by elephants?

My fieldwork in the Park and the meta-analysis of peer-reviewed studies I conducted implies elephant impact is evident at the smaller scales. In the Park, these signals were most prevalent at the local scale, and with the meta-analysis, in the short-term studies. Elephant impact is immediate at the point of "impact" — measuring structural changes will show that. By increasing the time and spatial scale, ecological processes such as other stochastic and deterministic disturbance events, dispersal, meta-population dynamics, competition and predation play a more prominent role, alleviating and compensating, or even masking possible negative effects of elephants.

Management implications

Conservation agencies around the world face a daunting challenge (Pimm *et al*. 2001). When Conservation International proclaimed Maputaland part of a biodiversity hotspot, they highlighted the importance of this region. These hotspots have two criteria, rich in endemic species threatened by high human densities and unsustainable land use practices (Myers *et al*. 2000). Formal conservation areas in these hotspots are therefore particularly important, and sound ecological theory should guide management decisions. Managing Tembe Elephant Park is no exception, and here I will discuss the interpretation of my study results to the management of elephants living in the Park.

Two points need consideration before I proceed. First, from a management point of view, ecosystems are complex and maintained by a range of scale dependant processes (e.g. Levin 1992). Management decisions may therefore, have unpredictable and non-linear outcomes. Secondly, African savannas, typified by dynamic and alternate stable states, can fluctuate between open grasslands, mixed woodlands and forests (Walker & Noy-Meir 1982; Dublin *et al.* 1990; Gillson 2004). Tembe Elephant Park contains an almost full spectrum of these different states, arranged in a heterogeneous and complex mosaic. This may complicate matters, but does not prevent the formulation of a relatively simple management solution for elephants living here.

Until now, the vegetation in the Park shows minimal signs of negative elephant impact. My recommendations may prevent future unacceptable and irreparable damage, before it happens. Elephants affect the open woodlands more than the closed woodlands and sand forests. However, although not investigated here, I cannot exclude the impact of frequent hot fires prevalent in the open woodlands as a contributing factor. Park's management prescribes the burning regime and elephants here thus do not operate in isolation.

If elephant numbers becomes a 'problem', three options are available: do nothing, regulate numbers within predetermined fixed asymptotes or let environmental limitations control their numbers. To do nothing is self-explanatory. Regulating numbers usually takes the form of culling (e.g. Astle 1971; van Aarde *et al*. 1999), translocation (summarised in Garaï *et al*. 2004) or immuno-contraception (Fayrer-Hosken *et al*. 2000; Pimm & van Aarde 2001). These controversial and often sensitive options give a false sense of predictability in their outcomes. Forcing constant values onto elephant population and demographic variables may not have the expected outcomes, such as decreasing population growth rates or stem the degradation of vegetation. Under these scenarios, the fences surrounding the Tembe Elephant Park and the provision of artificial water remain intact. Here in lie clues for the management. The Park still has a low elephant density – but compared to the free roaming elephants in southern Mozambique, already show some aberrant selection to landscapes. I ascribed this to the fences and redistribution of limiting resources such as water. Fences also trap the system into a fixed state that is unnatural for dynamic systems such as savannas. These constrains effectively decrease the scale at which elephants can operate and force agencies to continue their investigation into alternative and adaptive elephant management strategies. A circular argument ensues and spirals into a permanent conservation management predicament.

Elephant management is in dire need of a paradigm shift (similar to Wu & Loucks 1995; Briske *et al.* 2003). This shift should be from a perceived 'balance of nature' to 'flux of nature' by accepting non-linear and unpredictable dynamics (Gillson & Lindsay 2003), stabilised by large-scale processes and structure (Lewin 1986; Western *et al.* 1989; Bulte *et al*. 2004). This gives us a third option in solving this dilemma. If we allow for scale-dependant processes, such as metapopulation dynamics or other spatiotemporal models (Thomas & Kunin 1999) to operate, elephants may have the opportunity to establish sink and source populations through range expansion into marginal areas. In effect, by doing so, restoration principles (e.g. Dobson *et al*. 1997; Young 2000) combined with wildlife management techniques and elephant dispersal could reinstate migration patterns. Under this metaphor, the impact of elephants could be limited on the environment by allowing for the temporal alleviation of relatively high elephant densities. Dispersal in essence, may initiate recovering periods for other parts of the affected system. This argument also gives ecological and scientific impetus for the expansion of conservation areas.

I conclude – conservation managers, in their effort to conserve, enhance and maintain biological diversity, should always attempt to simulate scale-dependant ecological processes. From a philosophical point of view, I define the 'elephant problem' now as 'elephants being the result of a problem'. In addition, I would like to change the underlying statement in the debate, from 'elephants against diversity' to 'elephants are central to biodiversity'.

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