Chapter 6. General Conclusions

A habitat-based management plan for any species begins with the two-step process of first investigating the species distribution (i.e. where does it occur?) and continues by examining more fine scale questions on habitat utilization (i.e. what contributes to its presence in this area?). Developing a thorough knowledge of spatial patterns and selection processes is then used to help inform management decisions, conserve suitable habitat, and promote population persistence and stability (e.g. Boyce and McDonald 1999; Chetkiewicz et al. 2006; Larson et al. 2004; Nielsen et al. 2006). Within a habitat-based management plan, parks and protected areas are generally assumed to serve as the cornerstone for species conservation (e.g. Gaston et al. 2008). In reality, however, the world's parks and protected areas were often delineated following a very different set of criterion, preserving geological features (DiSilvestro 1993), areas of low productivity (Andrew et al. 2011), or other areas where humans were discouraged to live due to the prevalence of disease (Bengis et al. 2003). Consequently, protected areas often do not meet the spatial requirements of populations, particularly for large mammals (Cantú-Salazar and Gaston 2010; Hanks 2001; Morrison et al. 2007; Woodroffe 2000).

To increase the efficacy of parks in conserving large mammals, initiatives are striving to increase connectivity between once isolated protected areas, creating megaparks (van Aarde and Jackson 2007) and Transfrontier Conservation Areas (Hanks 2001, 2003). For elephants, the hope is that increasing connectivity between parks will promote regional population stability through the spatial structuring of population within the proposed framework of a metapopulation (van Aarde and Jackson 2007). Within a metapopulation, asynchronous population dynamics between interconnected subpopulations that are separated by distance could support regional population stability (Driscoll 2007; Olivier et al. 2009). However a metapopulation makes no predictions about habitat quality (Armstrong 2005), even though it is likely that spatial heterogeneity of resources and risks drives asynchrony (van Aarde and Jackson 2007; van Aarde et al. 2006). Conversely, the habitat-based approach focuses on identifying high-quality habitat, with little regard for demography (Armstrong 2005). For elephants, management may require the integration of the metapopulation concept to stabilize demography and the habitat-based approach to test assumption, model feasibility, and identify areas most conducive to support the structuring of a metapopulation.

In this thesis, I use habitat suitability models to test two pre-requisites for the spatial structuring of a population. The first thereof relates to the potential connectivity between populations. I found that the current spatial structuring of suitable elephant habitats allows for connectivity between populations; however connectivity was limited by a lack of surface water in the west and high human densities in the east (Chapter 3). Connectivity models based on habitat suitability allow for spatially explicit predictions of connectivity which then need to be validated with targeted field surveys. Studies on the genetic structuring of populations could assist efforts to evaluate whether modelled corridors are functional and used by elephants (e.g. McRae et al. 2008). From a study in progress on the genetic structure of elephant populations in the central portion of the study area, it appears that the male elephants are dispersing between populations (A. de Flamingh, *personal communication*). Yet, genetic studies are limited in their ability to explain the landscape factors contributing to connectivity, and they do not provide spatially explicit predictions which can be used to delineate and conserve corridors between subpopulations. When used in conjunction with the habitat-based approach, we may obtain a greater understanding of whether landscape features allow for connectivity and whether such structural corridors are actually functional linkages.

Next, a metapopulation assumes asynchronous population dynamics (Driscoll 2007; Olivier et al. 2009), and landscape heterogeneity could drive this asynchrony (van Aarde and Jackson 2007; van Aarde et al. 2006). Therefore, using a habitat-based approach I next investigated landscape factors that could contribute to heterogeneity in selection and mortality in northern Botswana. I found spatial heterogeneity in habitat selection patterns by elephants, as well as heterogeneity in the location of mortality events (Chapter 4). Both sources of heterogeneity were linked to landscape characteristics. Elephants selected areas close to water, where slopes are steep, and with moderate tree cover, and they had higher mortality risk when near humans (Chapter 4), particularly in highly suitable habitats (Chapter 5). The consequences that such functional heterogeneity may have for the structuring of populations need further investigation.

This thesis contains research across a spatial scale unprecedented in any single-species habitat selection study to-date, incorporating elephant populations across seven countries and a wide ecological gradient. Yet many questions still remain, and my hopes are that this research can serve as a baseline for these future studies. What remains is to identify the critical habitat components that contribute directly to demographic performance. This knowledge gap exists because the spatial and temporal scales with which habitat selection and demography operate are at odds. Habitat selection decisions occur at a fine scale, yet these fine-scale decisions have implications for the lifetime fitness of the individual and ultimately the demographic performance of the population across generations (Gaillard et al. 2010). Yet, the scale at which these processes operate is unknown for elephants. It may be that resource availability during a particular season (Illius 2006), at a particular stage in an individual's life (Trimble et al. 2009), or during a particularly difficult drought year unobserved for decades (e.g. Booth et al. 2012) has the greatest influence on shaping elephant population dynamics. This information would be invaluable in linking the habitat and metapopulation concepts, as habitat could then be used to directly predict, or potentially manipulate, elephant demographic performance.

Here, the metapopulation concept has provided a unifying framework by which to identify key questions. These questions were then addressed using a habitat-based approach, and the results contribute to the body of knowledge developing around the metapopulation concept. The large spatial scale on which I examined elephant's utilization of heterogeneous habitats effects the distribution of elephant and contributes to how they use space. Similarly, the uneven distribution of deaths and their association with people suggests that humans may contribute to the spatial distribution of elephants. Hence the structuring of elephants across space may be driven by the heterogeneity of resources and risks, as proposed by van Aarde and Jackson (2007), and this could contribute to the structuring of populations across space, possibly as a metapopulation.

As the largest land mammal in the world, savannah elephants also have large spatial requirements (van Aarde et al. 2008); therefore, it is understandable that elephant management ultimately comes down to space. While elephants can survive in small, isolated parks, the demographic processes that regulate population numbers cannot. A metapopulation for elephants may provide a solution (van Aarde and Jackson 2007). In southern Africa, human densities remain relatively low and natural habitats are still abundant in many areas, so we must plan for the future of these lands to ensure they meet the needs of both wildlife and people. The benefits of this framework are not one-sided, as communities near these natural landscapes often perform better than those far from parks (Ntumi 2012). This heterogeneous environment, with population sources that are beneficial for elephants and population sinks that support sustainable human needs, then creates a mutually beneficial system which ultimately serves to stabilize elephant numbers across a broad spatial scale.

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